



G2 General Considerations

This chapter describes general design considerations related to the construction, operation, and maintenance of municipal wastewater facilities. Topics covered in this chapter include general design criteria; flow measurement; odor control; mechanical, electrical, instrumentation, and control systems; safety; reliability classifications; and laboratory, personnel, and maintenance facilities.

G2-1 Design Criteria 5

G2-1.1 Treatment Regulations 5

G2-1.2 Design Loading, Treatment Plants 5

- G2-1.2.1 Hydraulic Loading 5
- G2-1.2.2 Organic Loading 5
- G2-1.2.3 Existing Systems 5
- G2-1.2.4 New Systems 5

G2-1.3 In-Plant Piping and Channels 6

G2-1.4 Design Flows, Collection Systems 7

G2-1.5 Plant Location 7

- G2-1.5.1 General 7
- G2-1.5.2 Flood Protection 7
- G2-1.5.3 Separation from Public Water Supplies 7
- G2-1.5.4 Access and Transportation Considerations 7

G2-2 Essential Components 7

G2-2.1 Multiple Units 7

G2-2.2 Water Supply 8

- G2-2.2.1 Potable Supply Connection 8
- G2-2.2.2 Recycling, Reuse Water 8

G2-2.3 Utility and Other Support Systems 8

G2-2.4 Laboratory, Personnel, and Maintenance Facilities 8

G2-2.5 Sewage Flow Measurement 8

G2-2.6 Sampling 9

G2-2.7 Preliminary Treatment 9

G2-2.8 Plant Details 9

- G2-2.8.1 Arrangement of Units and Access 9
- G2-2.8.2 Provisions for Flushing, Cleaning, and Draining 9
- G2-2.8.3 Pipe Identification 10
- G2-2.8.4 Corrosion 10

G2-2.8.5 Grading and Landscaping 10

G2-3 Siting Considerations and Impacts 10

G2-3.1 General 10

G2-3.2 Noise (Offsite Impacts) 11

G2-3.3 Visual Aesthetics 11

G2-3.4 Odor/Air Quality 11

G2-3.5 Bird and Animal Control 11

G2-3.6 Buffer Zones 11

G2-3.6.1 New Sewage Treatment Plants 11

G2-3.6.2 Existing Sewage Treatment Plants 11

G2-4 Flow Measurement, Sampling, and Splitting 12

G2-4.1 Treatment Plant Flow Measurement 12

G2-4.1.1 Purpose 12

G2-4.1.2 Flow Measurement 12

A. General 12

B. Flow Meter Selection 12

G2-4.1.3 Miscellaneous Design Considerations 13

A. Parshall Flumes 13

B. Other Flumes 13

C. Measuring Weirs 14

D. Venturi and Modified Flow Tube Meters 14

E. Magnetic Flow Meters 15

F. Sonic Flow Meters 15

G. Other Flow Metering Devices 15

G2-4.1.4 Sampling 15

A. Sample Devices 15

B. Sampler Design Considerations 15

C. Automatic Sampling Equipment 15

D. Manual Sampling 16

G2-4.2 Collection System Flow Measurement 16

G2-4.3 Flow Splitting.....16

G2-4.3.1 Purpose.....16

G2-4.3.2 Types of Flow Splitting Devices and
Their Application17

A. Flumes17

B. Weirs17

C. Control Valves.....17

D. Symmetry17

G2-4.3.3 Problems with Flow Splitting.....18

A. Upstream Conditions.....18

B. Inadequate Head/Pressure.....18

C. Approach Conditions.....18

D. Downstream Conditions18

E. Submerged Flow18

F. Improper Sizing of Primary Device19

1. Too Large.....19

2. Too Small.....19

**G2-5 Odor Prevention and
Treatment 19****G2-5.1 General Design
Considerations.....19**

G2-5.1.1 Estimating/Modeling Potential Odors ...19

A. Hydrogen Sulfide Generation and
Corrosion Potential20

B. Odor Dispersion.....20

1. Increasing Atmospheric Turbulence21

2. Increasing the Travel Distance.....21

3. Elevating the Emission Source21

G2-5.1.2 Collection System Design22

G2-5.2 Odor Prevention22

G2-5.2.1 Chemical Addition22

A. Chemical Oxidation.....22

1. Chlorine22

2. Hydrogen Peroxide23

3. Potassium Permanganate23

4. Iron Salts.....24

5. Anthraquinone24

6. Caustic Slug Dosing.....24

7. Nitrate Addition25

G2-5.2.2 Reaeration/Oxidation25

A. Oxygen Addition/Injection.....25

B. Air Injection.....26

C. Ozone.....26

G2-5.2.3 Operational Procedures26

G2-5.2.4 Containment.....26

G2-5.3 Odor Treatment.....27

G2-5.3.1 Tank Covers27

G2-5.3.2 Ductwork.....28

G2-5.3.3 Fans28

G2-5.3.4 Biofilters.....29

G2-5.3.5 Chemical Scrubbers29

A. Packed-Bed Wet Scrubbers30

B. Mist Scrubbers.....30

G2-5.3.6 Carbon Adsorbers.....31

**G2-6 Plant and Collection
System Details 32****G2-6.1 General 33**

G2-6.1.1 Arrangement of Units and Access.....33

G2-6.1.2 Provisions for Flushing, Cleaning,
and Draining.....33

G2-6.1.3 Pipe Identification33

G2-6.1.4 Corrosion.....33

G2-6.1.5 Operating Equipment33

G2-6.1.6 Facility and Equipment Size and
Scale Issues34

A. Throttling Valves.....34

B. RAS Pumps for Small Plants.....34

C. Aeration Basin Length-to-Width Ratios34

G2-6.2 Mechanical Systems..... 34**G2-6.3 Electrical Systems 34**

G2-6.3.1 General34

A. Governmental Codes and Regulations34

B. Manufacturer and Technical Society
Recommendations35

C. Plan Requirements.....35

G2-6.3.2 Electric Power Sources.....35

A. Reliability35

B. Primary Power Source35

1. General.....35

2. Service Voltage.....36

C. Standby Power Source.....36

G2-6.3.3 Power Distribution Within the Plant36

G2-6.3.4 Coordination.....36

G2-6.3.5 Reliability and Maintenance
Considerations.....37

A. General37

B. Lighting Systems38

C. Engine Generators38

1. Phase Alignment38

2. Muffling38

3. Louvers38

4. Fuel System.....38

5. Starting.....39

6. Switchgear39

7. System Expansion.....39

8. Starting Current.....39

D. Uninterruptible Power Supplies (UPS)39

E. Ground Fault.....40

1. Ground Fault Sensors.....40

2. Switching Equipment.....40

3. Grounding Circuits.....40

4. Grounding Dual-Fed Services.....40

F. Parts	40	G2-7 Safety	48
1. Standard Parts	40	G2-7.1 Safety Regulations	48
2. Replacement Parts.....	40	G2-7.1.1 Federal Regulations.....	48
G. Flooding	40	G2-7.1.2 Washington State Safety Regulations ...	48
1. Equipment.....	40	G2-7.2 Engineering, Design, and	
2. Conduits	40	Construction Safety	49
H. Miscellaneous.....	41	G2-7.2.1 Contracts	49
1. Oil-Insulated Equipment	41	G2-7.2.2 Prebid Specifications.....	49
2. Equipment Protection.....	41	G2-7.2.3 Preconstruction Meetings	50
3. Restart	41	G2-7.3 General Wastewater Safety	
4. Temperature Detectors.....	41	Hazards.....	50
5. Aluminum Conductor Substitution	41	G2-7.4 Hazardous Materials and	
6. Space Requirements.....	41	Chemical Handling.....	51
7. Utility Outlets	42	G2-7.5 Walking and Working	
G2-6.4 Instrumentation and Control		Surfaces.....	53
Systems.....	42	G2-7.6 Working Spaces.....	55
G2-6.4.1 General Requirements	42	G2-7.7 Fall Protection and Prevention	
A. Governmental Codes and Regulations	42	Systems	57
B. Manufacturer and Technical Society		G2-7.8 Confined Spaces.....	60
Recommendations.....	42	G2-7.9 Fire Control and Protection	
C. Plan Requirements.....	42	Systems	60
G2-6.4.2 Instrument and Control System		G2-7.10 Electrical Safety	61
Reliability Requirements.....	43	G2-7.11 Process Safety Management	
A. General	43	and Risk Management	
B. Design Considerations.....	43	Planning.....	62
G2-6.4.3 Coordination.....	43	G2-7.11.1 Process Safety Management.....	62
G2-6.4.4 Maintainability—Control Systems.....	44	G2-7.11.2 Risk Management Planning	62
A. Section Summary	44	G2-8 Reliability Classification	63
B. Identifying the Required Documents.....	44	G2-8.1 Definitions	63
C. Smart Instrumentation	45	G2-8.2 Reliability Components	64
D. PLC Documentation Software.....	45	G2-8.3 Electrical Power Sources	65
E. Reliability and Maintenance		G2-9 Laboratory, Personnel,	
Considerations.....	45	and Maintenance	
G2-6.4.5 Flexibility—Control Systems.....	46	Facilities	66
A. Flexibility Issues	46	G2-9.1 General	66
B. Plant Expansion.....	46	G2-9.2 Laboratory Facilities.....	66
G2-6.4.6 Technologies—Control Systems		G2-9.2.1 General.....	66
(DCS/SCADA) Design	46	G2-9.2.2 Space Requirements.....	66
A. Define the Functional Requirements	46	G2-9.2.3 Design	66
B. Key Functional Requirements	46	A. Location.....	67
C. Coordinated and Integrated Software		B. Layout.....	67
Functions.....	47	1. General.....	67
D. Historical Database Management.....	47	2. Storage and Cabinets.....	68
E. The Operator/Management Interface	47	3. Sinks	68
F. Moving Data to Other Systems.....	47		
G2-6.4.7 Coordination with Process Design	47		
A. Section Summary	47		
B. Design Coordination.....	47		
C. The Role of P&IDs	48		
D. Typical P&ID	48		

4. Benches and Tables.....	69
5. Air Handling	69
6. Safety	69
G2-9.3 Personnel Facilities	69
G2-9.4 Maintenance Facilities.....	70
G2-9.4.1 Maintenance Shop.....	70
G2-9.4.2 Vehicle Requirements	70
G2-9.4.3 Storage Requirements	71
G2-9.4.4 Yard Requirements.....	71
G2-10 References	71

Tables

G2-1. Design Basis for New Sewage Works	6
G2-2. Impact of Wastewater Characteristics on H ₂ S Formation	20
G2-3. Foul Air Ventilation Requirements.....	28
G2-4. Biofilter Design Criteria	29
G2-5. Carbon Adsorber Vessel Design Criteria.....	32
G2-6. Guidelines for Classifying Sewerage Works	64
G2-7. General Requirements for Each Reliability Classification.....	65
G2-8. Minimum Capacity of the Backup Power Source for Each Reliability Classification	66

G2-1 Design Criteria

This section contains general design criteria related to wastewater collection systems and treatment plants. Specific design criteria related to the collection, treatment, and disposal elements of the process are included in other chapters in this manual.

G2-1.1 Treatment Regulations

The wastewater treatment system shall produce an effluent that complies with the requirements of Ecology, state water quality standards, and federal law. The minimum standard shall be secondary treatment as defined in EPA regulation 40 CFR 133, as amended.

The state water quality standards for ground waters are in Chapter 173-200 WAC and for surface waters in Chapter 173-201A WAC. The state wastewater discharge standards and effluent limitations are contained in Chapter 173-221A WAC.

G2-1.2 Design Loading, Treatment Plants

G2-1.2.1 Hydraulic Loading

The hydraulic capacity of the treatment works should be based on the maximum expected flow. The process design of treatment units should be based on either the average design flow or the peak design flow, whichever is controlling. The following items should be determined from the observed rate of flow during the significant period of discharge. Items to be considered in determining design flows are as follows:

- Peak flow rates continuing over a length of time sufficient to adversely affect the detention time of treatment units or the flow characteristics in conduits.
- Applicable data from similar municipalities.
- Wet weather flows.
- Recirculation and inplant recycle flows.

G2-1.2.2 Organic Loading

The design organic loading should be computed in the same manner used in determining design flow.

G2-1.2.3 Existing Systems

Treatment plants designed to serve existing sewerage systems should be designed on the basis of characteristics of sewage obtained from the operating records of the treatment works.

The design engineer or owner shall provide a plan acceptable to Ecology for eliminating or handling excessive inflow/infiltration (I/I) so that there will be no discharge of inadequately treated wastewaters or impairment of the treatment process.

G2-1.2.4 New Systems

Sewage treatment plants to serve new sewerage systems should be designed on the basis of information in [Table G2-1](#). Numbers of persons per dwelling

should be based on planning projections derived from an official source. Any deviations should be based on sound engineering judgment substantiated in the engineering report.

Table G2-1. Design Basis for New Sewage Works

Discharge Facility	Design Units	Flow* (gpd)	BOD (lb/day)	SS (lb/day)	Flow Duration (hr)
Dwellings	per person	100	0.2	0.2	24
Schools with showers and cafeteria	per person	16	.04	.04	8
Schools without showers and with cafeteria	per person	10	.025	.025	8
Boarding schools	per person	75	0.2	0.2	16
Motels at 65 gal/person (rooms only)	per room	130	0.26	0.26	24
Trailer courts at 3 persons/trailer	per trailer	300	0.6	0.6	24
Restaurants	per seat	50	0.2	0.2	16
Interstate or through-highway restaurants	per seat	180	0.7	0.7	16
Interstate rest areas	per person	5	0.01	0.01	24
Service stations	per vehicle serviced	10	0.01	0.01	16
Factories	per person per 8-hr shift	15-35	0.03-0.07	0.03-0.07	Operating period
Shopping centers	per 1,000 sq ft of ultimate floor space	200-300	0.01	0.01	12
Hospitals	per bed	300	0.6	0.6	24
Nursing homes	per bed	200	0.3	0.3	24
Homes for the aged	per bed	100	0.2	0.2	24
Doctor's office in medical center	per 1,000 sq ft	500	0.1	0.1	12
Laundromats, 9 to 12 machines	per machine	500	0.3	0.3	16
Community colleges	per student and faculty	15	0.03	0.03	12
Swimming pools	per swimmer	10	0.001	0.001	12
Theaters, drive-in type	per car	5	0.01	0.01	4
Theaters, auditorium type	per seat	5	0.01	0.01	12
Picnic areas	per person	5	0.01	0.01	12
Resort camps, day and night, with limited plumbing	per campsite	50	0.05	0.05	24
Luxury camps with flush toilets	per campsite	100	0.1	0.1	24

*Includes normal infiltration

G2-1.3 In-Plant Piping and Channels

All piping and channels should be designed to carry the maximum expected flows. The incoming sewer should be designed for free discharge. Bottom corners of the channels should be filleted and pockets and corners where solids can accumulate should be eliminated. Isolation gates should be placed in channels to seal off unused sections where sewage solids might accumulate.

G2-1.4 Design Flows, Collection Systems

See [C1-3](#) and [Table G2-1](#).

G2-1.5 Plant Location

G2-1.5.1 General

Treatment plant sites should be located as far as practicable from any existing commercial or residential area or any area that will probably be developed within the plant's design life. The plant site should be separated from adjacent uses by a buffer zone and provided with ample area for any foreseeable future expansion.

Plant outfalls shall be placed so as to minimize impacts on commercial and recreational shellfish harvesting, and public water supply intakes. See [Chapter E2](#) for surface water effluent criteria.

G2-1.5.2 Flood Protection

The plant unit processes shall be located at an elevation which is not subject to the 100-year flood/wave action, or shall otherwise be adequately protected against 100-year flood/wave action damage. Newly constructed plants should remain fully operational during a 100-year flood/wave action.

G2-1.5.3 Separation from Public Water Supplies

Treatment plants, collection lines, and pump stations shall be a minimum of 100 feet away from wells providing public drinking water supplies. Greater separation may be required for lagoons depending upon the liner design.

G2-1.5.4 Access and Transportation Considerations

Year-round access to the plant shall be provided. Access to the plant site shall be capable of being secured. Entrance and service roads shall have adequate width and turning radii to permit bulk chemical deliveries if required by the process. Loading docks or other means of accessing and unloading delivery vehicles shall be provided. Adequate parking shall be provided.

G2-2 Essential Components

This section describes the essential components of a domestic wastewater treatment plant.

G2-2.1 Multiple Units

Multiple treatment units and properly located and arranged diversion piping should be provided so that any unit of the plant can be removed from service independently for inspection, maintenance, and repairs. Redundancy of critical conveyance equipment is included in this category.

G2-2.2 Water Supply

G2-2.2.1 Potable Supply Connection

An adequate supply of potable water under pressure shall be provided for use in the laboratory and at various locations around the plant for use by the staff. No piping or other connection that might cause contamination of potable water supply shall exist in any part of the treatment plant. See [E1-3.4](#) for a discussion of cross-connection control and backflow prevention.

To facilitate cleaning wetwells, tanks, and basins, water should be supplied at these points by means of a pressurized water system with hydrants or hose bibbs having minimum outlets of 1 inch. The water supplied may be from a nonpotable water system or the plant effluent. All piping and outlets containing nonpotable water shall be clearly identified. Any use of nonpotable water at the treatment plant shall meet DOH requirements.

G2-2.2.2 Recycling, Reuse Water

Water supply is a critical resource. Use of nonpotable, treated effluent is encouraged for landscaping, flushing, and similar purposes where public contact is minimal and potable water is not required. See [Chapter E1](#) for more information about water reclamation and reuse.

G2-2.3 Utility and Other Support Systems

Reliable power is required for most treatment and nongravity conveyance of sewage. Failure of such systems generally implies overflow and exposure to the public. Dual-feed power is recommended for all such facilities, and required for treatment plants.

Control systems are similarly recommended for redundancy, extending to gates, weirs, and remote operation of pumping facilities.

G2-2.4 Laboratory, Personnel, and Maintenance Facilities

See [G2-9](#).

G2-2.5 Sewage Flow Measurement

Facilities for measuring sewage flows shall be provided at all treatment works.

Plants with a capacity equal to or less than 50,000 gallons per day (gpd) should be equipped, and plants having a capacity of greater than 50,000 gpd shall be equipped, with indicating, recording, and totalizing equipment. This equipment should use strip or circular charts with flow charts for periods of either one or seven days, or a comparable means of documenting flows. The chart size should be sufficient to accurately record and depict the flow measured.

Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

Measuring equipment shall be provided which accurately measures flow under all expected flow conditions (minimum initial flow and maximum expected flow).

G2-2.6 Sampling

All treatment plant designs shall provide sampling points sufficient for both process control and regulatory needs. Provision shall be made to sample influent, effluent, and internal recycle flows, and any samples as required to operate the plant and to meet testing requirements. [G2-4](#) contains more detailed requirements.

G2-2.7 Preliminary Treatment

The purpose of preliminary treatment is to protect the operation of the wastewater treatment plant by removing any constituents that can clog or damage pumps or interfere with subsequent treatment processes from the wastewater. For example, removal of inorganic nonbiodegradable materials is essential for proper operation of biological wastewater treatment systems. Preliminary treatment devices include bar racks, grit removal, and coarse screens. See [Chapter T1](#) for detailed information on preliminary treatment.

G2-2.8 Plant Details

G2-2.8.1 Arrangement of Units and Access

Plant components should be arranged for greatest operating flexibility, economy, and convenience in installing future units.

Adequate access and removal space should be provided around all components to permit easy maintenance and/or removal and replacement without interfering with the operation of other equipment. Consideration should be given to the need for lifting and handling equipment used in the maintenance and replacement of all components. In addition, the placement of structures and devices such as eyes and hooks used to handle heavy and large components should be included in the design.

Lines feeding chemicals or process air to basins, wetwells, and tanks should be designed to enable repair or replacement without drainage of the basins, wetwells, or tanks.

G2-2.8.2 Provisions for Flushing, Cleaning, and Draining

Provisions should be made for flushing all scum lines, sludge lines, lime feed and lime sludge lines, and all other lines which are subject to clogging. Flushing can be accomplished using cold water, hot water, steam, and/or air, as appropriate. All piping subject to accumulation of compacted solids shall be arranged to facilitate mechanical cleaning and flushing without causing a violation of effluent limitations and without cross-connecting to the potable water system.

Provisions shall be made for dewatering each unit. The dewatering system should be sized to permit removal of basin contents within 24 hours. Drain lines shall discharge to points within the system so that adequate treatment is provided for the contents of the drained unit. Consideration should be given to the possible need for hydrostatic pressure relief devices. Provision should be made to prevent tank flotation following dewatering. Dewatering pipes should not be less than 4 inches in diameter.

Piping should be sloped and/or have drains (drain plug or valve) at the low points to permit complete draining. Piping should not be installed with isolated pockets which cannot be drained.

G2-2.8.3 Pipe Identification

To permit ready identification at any location, pipes should be color coded in the following standard convention:

Color	Indicates
Orange	Dangerous parts of machines or energized equipment and flammable gas lines.
Blue	Potable water.
Yellow	Chlorine.
Black	Raw sludge.
Brown	Treated sludge.
Purple	Reclaimed water.
Green	Compressed air.
Jade green	Nonpotable process or flushing water.
Gray	Wastewater.
Orange with blue letters	Steam.
White	Traffic and housekeeping operations.
Red	Fire protection equipment.

G2-2.8.4 Corrosion

Concrete, metals, control and operating equipment, and safety devices should be designed to withstand corrosion.

G2-2.8.5 Grading and Landscaping

Concrete or gravel walkways should be provided for access to all units. Where possible, steep slopes should be avoided to prevent erosion. Surface water should not be permitted to drain into any treatment units or the sanitary sewer except for runoff from grit removal, screenings, and sludge hauling facilities.

G2-3 Siting Considerations and Impacts

Most environmental impact mitigation will fall into the categories listed in this section. Effects on existing land use, or land character (such as wetlands and wildlife habitats), may require construction of mitigation measures that are not strictly required for treatment operation.

G2-3.1 General

Sewage treatment plant siting is discussed in [G2-1](#). Care is required to select a site that minimizes impacts to the public and the environment. This section addresses likely

adverse impacts which should be mitigated. An evaluation of the site for potential development is essential to selecting appropriate mitigation measures.

G2-3.2 Noise (Offsite Impacts)

Mitigate noisy equipment, notably air handling, high speed pumps, compressors, engine-driven generators, and so on. Transportation of goods to, and end products from, treatment facilities may also be a target for mitigation.

G2-3.3 Visual Aesthetics

Treatment facilities located near commercial and residential zones should consider screening and other techniques to blend the plant into its surroundings. See [G2-3.6](#).

G2-3.4 Odor/Air Quality

Emissions of any sort, but notably odors, should be controlled to avoid impacts. Onsite treatment is generally required, unless prevailing winds dilute and disperse odors over permanently nonpopulated areas.

G2-3.5 Bird and Animal Control

Where bird or animal infestation of treatment plant equipment causes housekeeping and sanitation problems, consideration should be given to the installation of devices to discourage or control the infestations. Wires, screens, or other barriers should be installed to keep birds and animals away from the equipment. These barriers should not obstruct access to the unit for operation and maintenance.

G2-3.6 Buffer Zones

G2-3.6.1 New Sewage Treatment Plants

All new sewage treatment plants should be designed with buffer zones. Buffer zones are areas of controlled or limited use within which residential uses, high-density human activities, or activities involving food preparation are prohibited. Minimum buffer zone widths and site screens will be established on a case-by-case basis, considering the process topography, prevailing wind directions, provision of covered units, and use of effective windbreaks in the overall plant design.

The prevailing wind direction should be determined by on-site data. Local weather station records may be used if they are demonstrated to be applicable. Attention should be paid to both moderate and high-velocity winds because high-velocity winds often have a different prevailing direction than moderate winds.

G2-3.6.2 Existing Sewage Treatment Plants

The upgrading of existing sewage treatment plants should include provisions for as large a buffer zone as possible under the specific existing conditions at each plant site. Wherever a demonstrated nuisance does exist, corrective action such as installation of windbreaks or odor control measures should be undertaken.

G2-4 Flow Measurement, Sampling, and Splitting

Flow measurement and sampling at the treatment plant are discussed in this section in detail because of the importance of accurately measuring and sampling flows throughout the treatment plant. Some of these flow measurement and sampling methods are also applicable for flows in the collection system and are not addressed in detail in this section.

Critical tankage (such as digesters, influent wetwells, and points that may overflow) should have level measurement. Some tanks may just need a high-level alarm while others will need a level indicator to show how much space is left in the tank. All measurements should be relayed to the control center for monitoring by an operator.

Flow splitting in general is addressed in this section, and is also discussed in Chapters [T2](#) and [T3](#) as it relates to topics in those chapters.

G2-4.1 Treatment Plant Flow Measurement

G2-4.1.1 Purpose

There are four reasons to measure plant flows and sample various waste streams in the treatment plant, as follows:

- (1) To assist in process control and operation of the treatment facility.
- (2) To help minimize the cost of operation and maintenance.
- (3) To provide a historical record of wastewater characteristics, flows, and process performance on which to base future plant expansions and modifications.
- (4) To meet the monitoring requirements of regulatory agencies. These requirements are usually contained in the treatment plant discharge permit.

G2-4.1.2 Flow Measurement

A. General

Metering devices within a sewage works should be located so that recycle flow streams do not inadvertently affect the flow measurement. All plants, regardless of size, should provide measurement of flow. See [G2-2](#).

B. Flow Meter Selection

Factors to be considered in selecting the method of flow measurement are as follows:

- Probable flow range.
- Acceptable head loss.
- Required accuracy.
- Fouling ability of wastewater.

G2-4.1.3 Miscellaneous Design Considerations

A. Parshall Flumes

Parshall flumes can be considered to measure raw sewage or primary effluent because of their freedom from clogging problems. Requirements to be observed when designing a Parshall flume installation are as follows:

- The crest shall have a smooth, definite edge. If a liner is used, all screws and bolts shall be countersunk.
- The pressure tap to the stilling well or float pipe should be made at a point two-thirds of the wall length of the converging section upstream from the crest.
- The pressure tap should be at right angles to the wall of the converging section.
- The invert (i.e., inside bottom) of the pressure tap should be at the same elevation as the crest.
- The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.
- The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well (never upward).
- Downstream elevations should be low enough to maintain free-flow discharge conditions and prevent excessive “backing up” in the diverging section, or provisions must be made to correct the measurement for submergence.
- The volume of the float well should be influenced by the conditions of flow. For rapidly varying rates of flow, the volume should be small so that the instrument float can respond quickly to changes in rate. For relatively steady flows, a large-volume, integral stilling chamber can be used.
- Suitable drain and shutoff valves should be provided to empty and flush out the float well.
- Means should be provided for accurately maintaining a level in the float well at the same elevation as the crest in the flume, to permit adjusting the instrument at zero flow conditions.
- Proper location of the flume is very important for accuracy. The flume should not be installed too close to turbulent flow, surging or unbalanced flow, or a poorly distributed velocity pattern. It should be located in a straight section of a channel without bends, immediately upstream of the flume. The flume should be readily accessible for both installation and maintenance purposes.

B. Other Flumes

Other types of flumes are also available for measuring plant flows. Manufacturers’ instructions should be followed.

C. Measuring Weirs

Weirs are appropriate for measuring effluent flows. For installation of weirs, the following criteria should be met. (Weirs included in these guidelines are V-notch, rectangular with end contractions, and Cipolletti.)

- The upstream face of the bulkhead should be smooth and in a vertical plane, perpendicular to the axis of the channel.
- The entire crest of a horizontal weir should be a level, plane surface which forms a sharp, right-angled edge where it intersects with the upstream face.
- The upstream corners of the notch must be sharp. They should be machined or filed perpendicular to the upstream face, free of burrs or scratches.
- The distance of the crest from the bottom of the approach channel (weir pool) should be not less than twice the depth of water above the crest.
- The water overflowing the weir should touch only the upstream edges of the crest and sides.
- The measurement of head on the weir should be taken as the difference in elevation between the crest and the water surface, at a point upstream from the weir a distance of four times the maximum head on the crest.
- The cross-sectional area of the approach channel should be at least six times that of the crest for a distance upstream from 15 to 20 times the upstream head on the weir.
- The head on the weir should have at least 3 inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

D. Venturi and Modified Flow Tube Meters

Requirements to be observed for application of Venturi meters are as follows:

- The range of flows, hydraulic gradient, and space available for installation must be suitable for a Venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.
- Venturi meters should not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.
- Cleanouts or hand holes are desirable, particularly on units handling raw sewage or sludge.
- Units used to measure air delivered by positive-displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.
- The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for five pipe diameters upstream of the

Venturi meter, unless treated effluent is being measured when straightening vanes are provided.

- Other design guidelines as provided by manufacturers of Venturi meters should also be considered.

E. Magnetic Flow Meters

Magnetic flow meters are appropriate for measuring influent, effluent, and process flows. They must be installed in a straight run of pipe at least four pipe diameters away from the nearest bend or pipe appurtenance. They should also be installed away from pump vibration and according to manufacturers' instructions. The pipe should flow full at all times.

F. Sonic Flow Meters

Sonic flow meters can be used on sludge process lines. They are subject to the same installation requirements as noted in [G2-4.1.3C](#).

G. Other Flow Metering Devices

Flow meters, such as propeller meters, orifice meters, pitot tubes, and other devices should only be used in accordance with the manufacturers' recommendations and design guidelines. The plant design shall include a section of open channel flow where electronic flow meters can be verified.

G2-4.1.4 Sampling

A. Sample Devices

Sampling devices must meet the requirements of the utility's NPDES permit, which generally cites Standard Methods for the Examination of Water and Wastewater and either an EPA (40 CFR Part 136) or Ecology regulation. The type of sampler and sample container used depends on what will be tested in the flow sample. Sample devices include dippers, vacuum lifts, and pumps (peristaltic, positive displacement, and centrifugal). The amount of lift should be a design consideration. Some wastewater plants may want to consider a discrete sampler to look at hourly loading over a 24-hour period. Some samplers have the capability of composite or discrete sampling.

B. Sampler Design Considerations

Samplers must maintain a sampling velocity which will keep the solids in the sample from settling. Composite samplers should be flow proportional and capable of sampling flow over a 24-hour period. Sampling lines should be large enough to carry suspended matter. A sampler should have a purge cycle to exhaust any material left in the sample line from the previous sampling. To comply with sample preservation, most samplers will need a means of refrigeration for the sample. Do not pump sample flow a long distance, because the sample lines develop growths which contaminate the sample. All sample lines should be cleanable.

C. Automatic Sampling Equipment

General guidelines to be used for automatic samplers include the following:

- Automatic samplers should be used where composite sampling is necessary.
- The sampling device should be located near the source being sampled, to prevent sample degradation in the line.
- Sampling transmission lines shall be avoided.
- If sampling transmission lines are used, they should be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines removable and easily cleanable. Minimum velocities in sample lines should be 3 ft/sec under all operating conditions.
- Samples shall be refrigerated unless the samples will not be affected by biological degradation.
- Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.
- Sampling access points shall be provided for return and recycle lines, wastewater inflows, and waste sludge lines.

D. Manual Sampling

Because grab samples are manually obtained, access to sampling sites should be provided in the design of treatment facilities.

G2-4.2 Collection System Flow Measurement

Today, with many utilities facing inflow and infiltration problems in the collection system, meters are being installed in pump stations so a history of flow can be established. All meters should have a data output to a data-collecting apparatus (such as a computer).

There is a wide variety of devices to measure flows in pipes. These meters must be installed in a straight run of pipe at least four pipe diameters away from the nearest bend or pipe appurtenance. They should also be installed away from pump vibration and according to manufacturer's instructions. The pipe must have full flow at all times. Magnetic flow meters are used for measuring influent, effluent, and process flows. Sonic flow meters can be used on sludge process lines. Designers should contact manufacturers for proper applications.

Portable flow monitoring equipment can be used to provide flow data at many points in the collection system.

Fixed and portable flow meters need to be maintained, kept clean, and in proper operating condition to ensure that accurate readings are achieved at all times.

G2-4.3 Flow Splitting

G2-4.3.1 Purpose

Flow splitting refers to dividing a flow stream into two or more smaller streams of a predetermined proportional size. Flow splitting allows unit processes such as aeration basins or secondary clarifiers to be used in parallel fashion. The flow is typically divided equally, although there are circumstances where this is not the case. For example, if the parallel unit

processes do not have equal capacity then the percentage of total flow feeding that unit might be equal to the capacity of that unit relative to the total capacity of all the parallel units. Flow splitting applies mainly to liquid streams but can also be an issue in sludge streams.

G2-4.3.2 Types of Flow Splitting Devices and Their Application

See “Isco Open Channel Flow Measurement Handbook” (Grant, 1995) for additional details on open channel flow splitting devices.

A. Flumes

Flumes are open channel structures and/or devices that produce a headwater (upstream) elevation related mathematically to the flow going through the structure as long as the flumes are operating in a nonsubmerged condition. The higher the flow, the higher the headwater elevation. Two or more identical flumes will pass the same flow with the same upstream head. If two or more identical flumes share the same headwater such as in a splitter box, they will effectively split the flow evenly among the flumes. One advantage in using flumes to split the flow is they can operate accurately with very little available head. Flumes are not recommended if the flow needs to be split unevenly because the flow is not linearly related to the throat width of the flume.

B. Weirs

Weirs are flat plates set in a channel which, like the flumes, produce an upstream head proportional to the flow going over the weir. Their main advantage is that they are fairly compact and inexpensive. Their main disadvantage is that they need a lot of head to operate properly. If the flow is to be split unevenly, suppressed weirs, circular weirs (glory holes), or Cipolletti weirs need to be used.

C. Control Valves

Control valves are used to split the flow when little or no head is available or space constraints prohibit the use of a splitter box. There are several valves suitable to control flow splitting. Butterfly valves can be used in large-flow situations where the chance of plugging with stringy materials is low. Pinch valves are ideally suited for flow control since there is nothing in the fluid to catch debris. Plug valves, ball valves, and other valves which do not plug are appropriate for flow splitting control. It is best if the valves are automatic and controlled by a flow signal from all the individual flow paths. In this way, the flow can be instantaneously totaled and portioned out in a predetermined way.

D. Symmetry

Symmetry has been relied on to split flows, with mixed results. Symmetrical flow splitting relies on the symmetry of the inlet structures to the upstream flow that is being split. One problem with reliance on this type of flow scheme is maintaining complete dynamic symmetry throughout the actual design flow range. Small variations in approach velocity, channel and pipe roughness, and downstream head losses can have a major impact on the accuracy of the flow split.

G2-4.3.3 Problems with Flow Splitting

A. Upstream Conditions

If the upstream flow velocity is above about 1 fps, significant velocity head can develop. If the flow is not perfectly symmetrical in relation to the splitting devices, the velocity head can develop uneven pressure head on the different flow splitting devices. This causes an uneven or unintended flow split.

A sufficient amount of head has to be available upstream of the splitting devices so as not to cause flooding of the upstream processes.

B. Inadequate Head/Pressure

If there is insufficient elevation difference between the upstream process and the downstream tanks, the flow splitting devices will not function properly. Submergence of the splitting device can occur. When a device is submerged, the tailwater depth prevents free fall and an aerated nappe from occurring through the device. The head on the device is no longer related in a consistent way with the flow going through the device. If one or more of the devices are submerged, but have the same headwater, the devices cannot reliably split the flow in a given proportion. The results are unpredictable and inconsistent.

C. Approach Conditions

The flow conditions approaching the splitting devices are critical to the success of the flow splitting effort. The flow velocity in the headwater area should be 1 fps or less to minimize any potential velocity head, which is described by the equation $V^2/2g$. The additional velocity head could turn into pressure head and/or head loss in an uneven fashion among the splitting devices, destroying the flow split. An uneven approach velocity distribution can also produce an unacceptable flow split.

D. Downstream Conditions

Downstream conditions can seriously affect the flow splitting capability of splitting weirs. Sufficient head must be available between process units to allow the proper functioning of the splitting devices. In particular, the splitting device needs sufficient free fall to the tailwater for it to work properly. One method of determining the downstream conditions of a weir to ensure an aerated nappe is given in "Open Channel Hydraulics" (Chow, 1959).

E. Submerged Flow

Submerged flow occurs when the tailwater depth is too high to allow free fall through the splitting device. Without free fall, the splitting device will not work properly. Certain devices such as flumes can tolerate a degree of submergence and still function. Weirs need at least 1 foot or so of free fall to allow for an aerated nappe. If a device is overly submerged, the flow through the device is affected by the tailwater depth, which destroys flow splitting.

F. Improper Sizing of Primary Device

For satisfactory results, the size of the primary flow splitting device needs to match the amount of flow being divided.

1. Too Large

If the primary flow splitting device is too large, it will not function properly. A minimum amount of head loss has to be generated through the device. For small flows, at least one-half foot of head loss needs to be generated. For larger flows, more head loss is required to split the flow.

If the flow over a weir is insufficient, it may result in the spillover running down the face of the weir. Because the nappe is no longer considered aerated, it acts as though it were a submerged flow. This can result in a pulsing of the flow over the weir as the nappe hugs and then releases from the weir. Results are unpredictable.

2. Too Small

If the primary splitting device is too small, it will generate too large of head to be accurate. It will also generate excessive head loss which may not be acceptable. Finally, the device would need a higher free fall to function.

G2-5 Odor Prevention and Treatment

This section describes the issues associated with odor prevention and treatment in wastewater collection and treatment facilities.

G2-5.1 General Design Considerations

The presence of odors associated with wastewater collection and treatment facilities can be a major source of public complaint. Odors are normally associated with anaerobic conditions in the transport and treatment processes, but can also occur because of industrial discharges. Even under the best conditions, wastewater can have odors which, if released to the atmosphere, would be considered objectionable to the public. Work has been done to model the production of odors in the collection system and atmospheric dispersion models have been developed to help predict odor release impacts to the surrounding area. General approaches to odor control include prevention of production through facility design, facility operation or chemical/biological inhibition, containment, and collection and treatment. Hydrogen sulfide corrosion concerns must be addressed in addition to the issues associated with odor control whenever containment is utilized.

G2-5.1.1 Estimating/Modeling Potential Odors

Odor production in the collection system has been studied extensively and materials are available for estimating the rate of hydrogen sulfide production. Once odor levels are known or estimated, dispersion models can be utilized to predict the potential range and magnitude of these odors.

A. Hydrogen Sulfide Generation and Corrosion Potential

A complete model for sulfide generation in a force main and for sulfide generation and corrosion in gravity sewers is presented in ASCE Manual No. 69. In order for this model to be utilized, specific information needed includes the following:

- Concentrations of organic material and nutrients (BOD).
- Dissolved oxygen and/or nitrate.
- pH.
- Temperature.
- Stream velocity.
- Surface area of the pipe.
- Detention time.

The impacts of variations in the characteristics of the wastewater flow on H_2S and odor generation and the anticipated range of values of these characteristics for the force main flow are shown in [Table G2-2](#).

Table G2-2. Impact of Wastewater Characteristics on H_2S Formation

Parameter	Impact of H_2S Formation	Anticipated Range in Force Main
BOD	Increase in BOD increases the potential for H_2S formation.	200 to 350 mg/L
pH	Decrease in the pH increases the potential for release of H_2S gas.	6.8 to 7.2
Temperature	Increase in temperature increases the potential of H_2S formation.	62 to 72 ° F
Detention Time	Increased detention time in the force main under anaerobic conditions increases the potential for H_2S formation.	9 to 34 hours

B. Odor Dispersion

There are a number of atmospheric dispersion models which can be used to predict odor concentrations surrounding a release point. One such model is presented in the WEF Manual of Practice No. 22. As with the previous model, data collection is required in order to utilize this model. Specific information needed includes:

- Plume height.
- Emission rate.
- Wind speed at point of emission.
- Height of receptor.
- Position of receptor with respect to wind direction.
- Downwind distance of receptor from source.
- Stability class, which affects vertical and horizontal dispersion.

While it is possible to utilize tables contained in the WEF manual to obtain estimates of the odor dispersion, it is often more efficient to contract with a

firm having specific expertise in running these types of models. The use of dispersion models coupled with hydrogen sulfide generation models to estimate concentrations can be used to estimate the level of treatment required to prevent odor complaints. Design of gas discharge stacks and vents is important in maximizing dispersion of odor in the atmosphere. Also, layout and site vegetation can play an important role in minimizing odor.

Odor regulations are generally aimed at reducing odor impacts to nearby receptors rather than reducing discharge mass or quantities of specific odor-producing compounds. As a result, dispersion and dilution of odor emissions is generally considered an acceptable means of reducing odor impacts. Dilution is ordinarily accomplished at wastewater treatment facilities by increasing atmospheric turbulence, increasing distance between odor source and receptors, or elevating the emission source by means of a tall stack.

1. Increasing Atmospheric Turbulence

Turbulence in the atmosphere helps disperse and dilute odors. Turbulence is generally a function of atmospheric conditions in the vicinity of the discharge. An increase in atmospheric turbulence can be produced by several mechanical means, including adding structures and/or vegetation. This might be accomplished by adding a band of trees around the facility perimeter. Trees would tend to increase turbulence by forcing the odor plume upward over the trees, allowing mixing with air to occur as the plume settles back toward the ground. Vegetation can also work as a filter by adsorbing some of the odorous compounds onto the foliage. Vegetation is not always effective, however, particularly if the vegetation is not sufficiently dense. In such cases, constructed barriers and mechanical fans can be added to promote dispersion.

2. Increasing the Travel Distance

A buffer zone between the odor source and nearby receptors allows dispersion. If the width of the buffer zone can be increased, then odor impacts outside the buffer zone will be reduced. Care should be exercised, however, in siting plant facilities to make sure odor-emitting structures are kept as far from the property boundary as possible. Selecting site locations near the site perimeter may necessitate the use of more active odor-control measures.

3. Elevating the Emission Source

Increasing the elevation of the emission by means of adding a stack generally results in lower downwind impacts. The stack allows greater atmospheric dispersion and increased dilution before the plume reaches downwind ground-level receptors. Stack effectiveness depends in large part on temperature and moisture content of the gases being emitted. Warmer, drier gases stay aloft longer, allowing more dilution and dispersion. Elevation of atmospheric discharges may increase their visibility. For these reasons, an elevated stack alone is not likely to provide a satisfactory means of resolving an odor emission problem.

G2-5.1.2 Collection System Design

Design of gravity interceptors, tunnels, force mains, siphons, wetwells, and related facilities needs to include features to minimize the generation of sulfide and other odorous compounds formed by anaerobic biological activity. The design of the collection system will have an effect on the production and release of odors. Factors to be considered are as follows:

- Pipe slope.
- Transition structures.
- Manholes.
- Proximity to receptors.
- Inverted siphons and force mains.

G2-5.2 Odor Prevention

Odors can be prevented by chemically or biologically inhibiting their production. Operating strategies can be modified to create conditions which are less conducive to odor generation or release. Finally, containing foul air beneath a cover or in an enclosed space, ventilating the enclosed space, and treating the foul air with some kind of treatment system will reduce odor impacts. See [C1-9.6](#) for odor control related to collection systems.

G2-5.2.1 Chemical Addition

Chemicals can be added to various points within the collection system to control odors. Control approaches include chemical oxidation, biological interference, precipitation of sulfides, and biological inhibition. Chemical addition to wastewater streams is used to control the concentration of contaminants, generally sulfides, in the liquid phase. Chemical addition is used when liquid treatment is more cost-effective than allowing the contaminants to become airborne and employing gas-phase treatment of the same contaminants. Liquid-phase treatment rarely eliminates the need for gas-phase treatment, but rather supplements gas-phase treatment. Gas-phase treatment can be reduced by liquid phase treatment to a level at which, for instance, biofiltration can be employed or the life of gas-phase carbon adsorbers can be extended. In practice, liquid-stream chemical addition is used to reduce relatively high liquid-stream contaminant concentrations. In most cases, the techniques discussed below are most effective in force main situations, where sulfide generation is most commonly found. They are less commonly applied to gravity flow systems which have an air-liquid interface since oxygen transfer will tend to keep the flow aerobic. They may still be useful in situations where there are upstream sources of sulfide; however, care must be taken to avoid turbulence and subsequent release of the H_2S to the gas phase.

A. Chemical Oxidation

1. Chlorine

Chlorine is a powerful and relatively cheap chemical oxidant. The reactive component of any chlorine application in water is the hypochlorite ion, regardless of whether chlorine gas or a sodium hypochlorite solution is used. Because chlorine is very reactive it reacts with many compounds found in wastewater including H_2S . This

high reactivity can also be a disadvantage, however, because chlorine indiscriminately oxidizes any reduced compound in wastewater. The competing side reactions require an overfeeding of chlorine to ensure sulfide oxidation. It has been shown that between five and 15 parts by weight of chlorine are required to oxidize one part sulfide.

For applications requiring less than approximately 140 kg/d Cl_2 , hypochlorite solution feed equipment is often the most economical. For applications requiring greater amounts of Cl_2 , chlorine gas is required. Using chlorine gas requires greater maintenance and safety costs.

Best results are achieved when the chlorine solution is mixed rapidly and thoroughly with the entire wastewater flow. Direct injection of gas is dangerous because it may cause downstream fuming with the potential to release dangerous chlorine gas.

Chlorine also acts as a bactericide. Depending on the point of application and dose, it can kill or inactivate many odor-causing bacteria. On the other hand, since it is nonselective, it may also kill organisms beneficial to wastewater treatment. Chlorine is a hazardous material, and any use of chlorine must include consideration of health and safety.

2. Hydrogen Peroxide

Hydrogen peroxide is a commonly used oxidant that oxidizes H_2S to elemental sulfur or sulfate depending upon the pH of the wastewater. It is normally delivered as a 50-percent active solution. Typical applications require one to three parts hydrogen peroxide per one part sulfide. The reaction takes place quickly and most of the hydrogen peroxide is consumed soon after dosing.

Several advantages of hydrogen peroxide are: reactions with sulfide and other odor causing compounds yield harmless byproducts; decomposition of excess hydrogen peroxide into water and oxygen increases the DO concentration of the wastewater and produces no chemical residue; and feeding equipment is relatively easy to operate and maintain if safety procedures are followed closely. Hydrogen peroxide can only control odors for a short retention time, thus it is best suited for control of a point source by dosing just upstream of the source of odors. Under normal conditions, injection must occur at a point at least 15 minutes ahead of potential release points to ensure complete reaction.

Because hydrogen peroxide is very reactive with organic materials, the maintenance and operation of such a system requires special training, procedures, and safety practices.

3. Potassium Permanganate

Potassium permanganate is a strong chemical oxidant that oxidizes H_2S to elemental sulfur or potassium sulfate. Studies have shown that approximately six to seven parts potassium permanganate are required for each part sulfide oxidized. Potassium permanganate is expensive and can be explosive if contaminated with acids or organics. For these

reasons is not widely used as an odor control oxidant in the US. It also produces an insoluble chemical floc (manganese dioxide). Some success has been encountered in dewatering operations where the permanganate helps to reduce odor and concurrently improves dewaterability.

4. Iron Salts

Aqueous salts of iron form a very insoluble precipitate, FeS , with H_2S . This is in contrast to other odor control chemicals which oxidize the H_2S gas. Either ferrous or ferric salts are used. Some studies have found that a combination of both ferrous and ferric salts work better for H_2S control than either alone, but such a blend is not commercially available. The oxidation/reduction status of the sewer plays a large role in determining which species will be more effective. In reduced conditions Fe(III) is better at reducing H_2S levels than Fe(II) . However, a little O_2 greatly improves the effectiveness of Fe(II) . Thus, Fe(II) is a more effective additive to a freely flowing sewer, where some O_2 is always present.

The iron sulfide precipitate is the size of talc particles and turns the sewage black. It is a flocculant that increases the rate that other solids settle out. The characteristics of the wastewater determine whether or not it is a problem at the treatment plant.

Iron addition is commonly used in anaerobic digesters to reduce odors associated with dewatering and digester gas. Since the system is anaerobic, Fe(III) , which is less expensive, is commonly used. Iron salts are acidic, so care must be exercised to avoid excessive alkalinity reduction in the digester.

5. Anthraquinone

Anthraquinone is a chemical that blocks bacteria from using sulfate in its metabolic processes. It is only slightly soluble and must settle into the slime layer to become effective. When contacted by anthraquinone, the bacteria in the slime layer are inactivated for a period of several days up to six weeks. After this time, the bacteria start sulfide production again if not retreated. Because of the low solubility, it is only partially effective in force main application and fast gravity main flows.

6. Caustic Slug Dosing

Sodium hydroxide is a strong caustic solution. It controls H_2S by shifting the sulfide equilibrium from the H_2S form to the dissolved hydrosulfide HS^- forms. The continuous addition of sodium hydroxide would prevent the release of H_2S , but is not a cost-effective solution. Periodic slug dosing with sodium hydroxide, however, can be effective in a sewer system. It works not by shifting the chemical equilibrium, but by inactivating or killing the biological slime layer, which is responsible for the generation of H_2S . The slime layer will regrow, but it will take several days or weeks for it to resume full sulfide production.

For such a system large quantities of caustic are needed and the slugging can have adverse effects on nearby treatment plants. Treatment facilities must have equalization facilities to deal with the elevated pH levels or they must neutralize the wastewater with acid before treatment. These procedures add to the cost of a slug dosing operation and may be prohibitive. Normal operation requires that the pH in the line be raised to greater than 11 for at least 15 minutes. Higher dosages and or longer dosage periods may initially be required to remove the accumulated slime layer. Caustic slug dosing is most effective for force mains.

7. Nitrate Addition

Facultative and obligate anaerobic bacteria, which are responsible for sulfide production, prefer nitrate to sulfate as an oxygen source. This results in the production of nitrogen gas and other nitrogenous compounds rather than hydrogen sulfides. Nitrate can be obtained in a variety of liquid and dry forms, mostly as sodium or calcium nitrate. It has several advantages over other control options. It is consumed more slowly than dissolved oxygen in wastewater systems; it is nonflammable and nonhazardous, requiring no special containment or safety devices; and it produces only minor flocculants to increase solids production.

Nitrate functions as an alternate source of oxygen and thus inhibits the production of H_2S . It also has been found to be effective at reducing the existing concentration of H_2S in collection systems by enabling biological oxidation of the H_2S back to sulfate. Dosage rates are dependent upon the length of time in the conveyance system, with higher dosages being required for longer detention times and where H_2S is already present. Dosage has been experimentally determined to be 2,400g nitrate-oxygen per kilogram sulfide (2.41lb/lb). Bioxide is a commercially available form of calcium nitrate sold for use in wastewater treatment.

G2-5.2.2 Reaeration/Oxidation

A. Oxygen Addition/Injection

Because most odors are produced by anaerobic conditions in the sewage system, the addition of oxygen to the system can decrease odors from the sewage. The addition of oxygen can either directly oxidize the odor-causing compounds or create the aerobic conditions necessary for aerobic bacteria to carry out this function through metabolic processes. The addition of oxygen to the system by creating aerobic conditions can also prevent the formation of odorous compounds by allowing aerobic bacteria to dominate anaerobic bacteria in competition for available food in the sewage.

The addition of pure oxygen gas accomplishes the same thing as the addition of air, but only one-fifth as much is added to achieve the same dissolved oxygen concentration. This means that a smaller volume of gas is needed to achieve the same oxygen transfer to the wastewater. Oxygen can either be generated on-site or purchased commercially. It has the further advantage of not containing nitrogen and thus it significantly

reduces the potential for air binding. It also allows treatment of longer detention-time force mains.

B. Air Injection

Air is a readily available source of oxygen. Air injection may also cause turbulence since it is four-fifths other gasses, which will result in the release of odoriferous gasses. It has proven to be successful when injected at the head of short- to moderate-length force mains. Problems have been encountered in force mains that have high points since there is the potential for “air” binding and reduced flow capacity.

C. Ozone

Ozone is an extremely powerful oxidant that can oxidize H_2S to elemental sulfur. Ozone is unstable and must be generated on-site. Ozone is a disinfectant. It is also toxic to humans at concentrations over 1 ppm. Although it has been shown to reduce odors in air, effectiveness in reducing odiferous compounds in sewage has not been documented. Since it is generated from air, the problems associated with air injection into sewage apply to ozone injection. It also requires fairly sophisticated equipment, which is not readily utilized at unstaffed sites.

G2-5.2.3 Operational Procedures

There are a number of operational procedures which can be utilized to limit the production or release of odors. Probably the most important is good housekeeping. Routine hosing and debris removal at pump station wetwells and within the treatment plant can significantly reduce odor production. Operation of wetwells is also an important factor. While it may be more energy efficient to operate at higher wetwell levels, this increases detention times and the potential for the development of anaerobic conditions and H_2S production. Fill and draw pump stations should consider more frequent pumping while level set points on variable speed pump stations should be lowered where odor is an issue.

Odor containment prior to treatment is often used as discussed in [G2-5.2.4](#). This often creates problems for operations personnel because of inconvenience. Containment is only effective if it is not compromised by leaving hatches or doors open or otherwise compromising the containment. It requires an ongoing education program to ensure that odor control procedures and design intentions are maintained.

G2-5.2.4 Containment

The first step in any foul air treatment system is containment of the odorous air. If fugitive emissions under normal operation are not eliminated, the whole odor control strategy is negated. This applies both to covered process tanks and channels and to occupied spaces.

Collection of foul air from covered tanks and channels has traditionally been based on air exchange rates. A moderate exchange rate may be required to reduce condensation and corrosion, or a higher exchange rate may be needed to allow utilization of the enclosed space above a clarifier or CSO tank, for example.

Collection of foul air for prevention of air leakage through cracks, leaks, and other penetrations in a cover primarily depends on establishing a negative pressure within the enclosed headspace. The negative pressure is established by exhausting air from the enclosed headspace, which draws air into the headspace through the various openings in the cover. The negative pressure is a function of the air velocity through those openings.

Factors to be considered in type and location of covers are:

- Permanency (fixed, removable).
- Ease of removal (by crane, manually).
- Accessibility/visibility (hatches, clear panels).
- Aesthetics (sun reflection, camouflage).
- Sealing (gasketed, permanently sealed).

As discussed above, containment will only be effective if it is not compromised. While containment will increase the difficulty associated with operating covered units, it is important that every effort be made to minimize the inconvenience and maximize worker safety. As an example, hatches which need to be opened to observe internal equipment should be readily accessible and easily opened (e.g., not blocked by railings or too heavy to lift).

G2-5.3 Odor Treatment

Odorous air removed from collection systems and treatment units can be treated to destroy odorous compounds before release. As indicated previously, the level of treatment required can be determined through the use of dispersion modeling.

The following equipment items are likely to be used for odor facilities.

G2-5.3.1 Tank Covers

Tank covers may be concrete, aluminum, plastic, or fiberglass. Use of covers may require that the area under the cover be ventilated for corrosion protection. Ventilation requirements will depend on the use of the area being ventilated.

Ventilation of structures is used to provide an environment suitable for human occupancy by purging the structure of odorous, toxic, and hazardous gases with outside fresh air; extend the life of an enclosure and/or its equipment by purging the area of corrosive gases; create a negative pressure within the structure to prevent the escape of fugitive emissions; or any combination of the above. The air-exchange-rate principle must be used for occupied spaces such as free entry wetwells and screen rooms. The negative pressure principle is typically used for covered tanks and channels. The ventilation requirements for situations typically encountered in wastewater facilities are shown in

[Table G2-3](#).

Table G2-3. Foul Air Ventilation Requirements

Ventilation Needs	Requirement
Areas where operator access is frequently required (wetwells, screen rooms, domed tank covers).	15 air changes per hour continuously in occupied space.
Potentially corrosive areas where operator access is treated as confined space entry (submersible pump wetwell).	6 air changes per hour continuously to reduce corrosion. Confined space entry if occupied.
Foul air withdrawal rate to create a negative pressure (flat covers over channels and tankage).	0.5 to 1.5 cfm/sq ft of cover area, depending on cover leak-tightness.
Canopy hoods over equipment or tanks.	400 fpm velocity through perimeter space.
Negative pressure inside covered areas.	0.05 to 0.1 inch of water column.

Handrailing around the tank must be provided if removable covers are installed on otherwise open tanks. The handrailing may be the permanent type, or a method of temporarily installing handrailing must be provided. Hand railing around the tank must be provided if removable covers are used. Covers may be removed by hoist, crane, or manually; if manually, the maximum cover weight must meet OSHA standards. Consideration should be given to issues of fall protection where covers must be removed manually. Staff also need to be aware of confined space requirements associated with covered units, and design consideration should be given to this issue.

G2-5.3.2 Ductwork

Ductwork may be constructed of galvanized steel, aluminum, stainless steel, fiberglass, or polyethylene materials. The choice will depend primarily on the corrosiveness of the conveyed air and of the external environment. The most cost-effective ductwork that meets the corrosion demands should be used. Duct sizing would be based on velocity (to reduce noise) and air friction loss (to conserve fan energy).

G2-5.3.3 Fans

Fans to exhaust or transfer foul air and to blow the foul air through the treatment system are normally constructed of aluminum or fiberglass reinforced plastic material. They would likely be the same material as the associated ductwork. They should be centrifugal, with the bearings located outside the air stream. These fans or blowers are widely available in sizes up to 60,000 cfm. In areas where space is limited (particularly for transfer fans), in-line centrifugal duct fans may be used but are not recommended because of their more difficult maintenance requirements, including removal from the ductwork.

The overall foul air system should be designed such that building space exhaust fans would develop sufficient pressure to deliver the foul air stream into the ductwork exiting the building. From that point, the odor control treatment system fan would power the air stream. If the odor control system is nonoperational, the building space exhaust fan should bypass and exhaust to the atmosphere. This type of fan should be AMCA certified. Redundant fans are not recommended.

G2-5.3.4 Biofilters

Biofilters are a simple and inexpensive method of biological treatment for odor control. The main component of this system is a bed of compost, tree bark, peat, or soil, about 3 feet deep, through which the fouled air is blown. The material in the bed of the filter provides an environment for a diverse culture of microorganisms. The organisms eat the gaseous pollutants as they pass through and are trapped by the filter bed. Maintaining the right temperature and humidity in the filter bed is important. The microorganisms must be sustained so they can eat the pollutants. Without the microorganisms, the filter will perform like an adsorption filter which will quickly reach its maximum adsorption capacity. Such a filtering system can work very well if care is taken to ensure proper operating conditions.

Cost effectiveness is the greatest advantage of this system. It requires a substantial amount of real estate to operate correctly. The system is also environmentally friendly as few if any chemicals are necessary for operation. The main disadvantage of a biofilter for control of H_2S is that the acids generated by the degradation of H_2S eventually destroy the organic media. They also require a fairly low surface velocity so dilution and dispersion of any remaining odors is limited.

Biofilters may be open or closed bed, depending on space constraints and aesthetics. Biofilter media would be an appropriate combination of organic and porous materials. Design criteria for biofilters are provided in [Table G2-4](#).

Table G2-4. Biofilter Design Criteria

Parameter	Criteria
Media properties pH Particle size Pore volume	≈ 7 ≤ 0.75 inch 60 percent (minimum)
Pressure drop	≤ 3 inches of water column per foot of media depth
Foul air Moisture Temperature drop Inlet H_2S concentration	Add moisture to provide 100-percent RH in the inlet foul air to biofilter 46 to 105 ° F Less than 25 ppm (volumetric measure)
Media depth Open bed Closed bed	3 to 4 feet 5 feet (maximum)
Foul air residence time	60 seconds (minimum)
Surface loading	2 to 4 cfm/sq ft

G2-5.3.5 Chemical Scrubbers

Chemical scrubbers work on the principle of absorption of the contaminant from a gas stream by dissolving it in a selective liquid solvent. In addition, chemicals are generally added to the scrubbing liquid to oxidize the constituents after they have been absorbed.

Odor removal by gas scrubbers is limited in that components in odorous gas streams may be insoluble in water. Substitution of a suitable, solvent-scrubbing liquid is then required to cause the physical transfer of the

contaminants to the liquid phase. The removal of extremely small quantities of odorous air contaminants is also troublesome. Low concentrations of organic vapors often require a long contact time and the use of large quantities of solvent. The economics for absorption of organic compounds are, therefore, unfavorable unless the solvent can be regenerated or used as another process makeup stream.

Chemical scrubbers are available in two basic configurations—packed-bed towers and mist towers.

A. Packed-Bed Wet Scrubbers

The most common chemical scrubber is the packed-bed wet scrubber. Scrubbing liquid is sprayed over packing through which the odorous gases pass. The foul air is passed through the gas-liquid contacting packed bed, then through a mist eliminator and exhausted to the atmosphere. The purpose of the packing is to promote turbulent mixing of liquid and gas and, hence, increase the gas-liquid mass transfer rate. The scrubbing liquid is collected in the bottom of the vessel and recirculated.

Fresh chemicals are added to the system, and a small amount of spent solution is bled off to drains. Generally, packed-bed scrubbers operate with relatively weak circulating solutions to avoid too much chemical loss in the scrubber blowdown. When contaminants (such as hydrogen sulfide) are readily absorbed and oxidized in aqueous solutions, packed-bed scrubbers can perform with reasonable efficiency.

However, organic sulfur compounds that are not absorbed efficiently at the elevated pH required for H_2S absorption usually are not controlled to a great extent in packed bed scrubbers. In addition, other odorous organic compounds, such as amines and aldehydes, may not be absorbed efficiently at elevated pH levels. As a result, exhaust gases can exhibit low hydrogen sulfide concentrations but have high odor levels. It is possible to customize the odor scrubber operation depending on the primary contaminant present. Scrubbers treating primarily H_2S are operated at elevated pH levels. If ammonia and amines are the primary odor source, operation in an acidic range will provide greater removal. Highly complex mixtures may require multi-stage units to effectively treat all odorous compounds present in the air stream.

The chief operating problem with packed-bed scrubbers is scaling. Dissolved constituents in the circulating solution will concentrate so that potential for scaling always exists. Scaling results in high pressure drops and channeling of the liquid and gas streams. These problems can increase energy cost and decrease the rate of mass transfer. Alleviating scaling potential may require excessive solution blowdown, which significantly increases chemical costs. Softening the makeup water reduces the scaling problem. Packed-bed scrubbers, with their associated chemical startup systems, have a higher capital cost than carbon adsorbers or biofilters. They become cost effective at medium to high contaminant concentration levels and at high air-flow rates.

B. Mist Scrubbers

An alternate chemical scrubber design, known as a “mist scrubber,” offers a significantly different approach to wet chemical scrubbing of odorous

gases. In this design, a relatively strong chemical solution of sodium hypochlorite and caustic is introduced through an air-atomizing nozzle. This nozzle creates a fine mist consisting of millions of very fine droplets (typically about 20 microns or less in diameter) that are introduced into a relatively large vessel. The very high surface-area-to-volume ratio of the fine droplets, coupled with the high gas-liquid contact time and high chemical concentration, creates efficient hydrogen sulfide absorption and oxidation.

Removal of organic sulfur compounds tends to be better in this type of scrubber because the oxidant concentration is higher and the fine droplets promote greater direct contact of odorous compounds and scrubbing chemicals. The mist scrubber has the advantage of using a chemical solution that is immediately drained from the scrubber as condensate that forms on the walls of the scrubber vessel after a single pass.

The drawbacks to this design are greater mechanical complexity (compressors and associated peripheral equipment) and a tendency for some air-atomizing nozzle designs to plug frequently. Another disadvantage is that some mist is inevitably carried in the treated air discharged from the scrubber.

Mist scrubbers should use less chemicals than packed-bed scrubbers. However, the reduction in chemical usage is not great, and the cost savings may be negligible when additional costs are considered for larger vessel sizes (or additional vessels), compressors, and nozzle maintenance required with mist scrubbers.

G2-5.3.6 Carbon Adsorbers

Activated carbon has been widely used as an adsorbent for odorous air treatment at wastewater treatment facilities. Because the main odor-causing agent at most facilities is H_2S , the carbon is often impregnated with sodium hydroxide to make it more effective at removing H_2S . The alkali-impregnated carbon not only adsorbs the H_2S , but chemically converts it to elemental sulfur. This allows the carbon to continue to adsorb and convert H_2S , greatly enhancing its H_2S removal capacity over ordinary activated carbon which can only adsorb H_2S . The improved H_2S removal comes at the cost of reduced organic removal. If organics rather than H_2S is the major source of odor, unimpregnated carbon is the better choice. Where the air stream contains both, it may be appropriate to utilize either a two-stage system with both impregnated and unimpregnated carbon or a single unit with both impregnated and unimpregnated carbon. In either case, the unimpregnated carbon should be the first product to be contacted by the air stream.

The life of an activated carbon bed is limited by the quantity of compounds being removed. The more compounds that the carbon removes the shorter its effective lifespan. Unimpregnated carbon can be reactivated with a high temperature steam treatment or thermally regenerated. This is normally done by returning the product to the manufacturer. In the case of chemically impregnated carbon, regeneration is accomplished by rinsing and soaking with a concentrated hydroxide solution. Impregnated carbon should generally be replaced instead of regenerated a third time.

Vessels containing the carbon may be concrete or fiberglass. Fiberglass should be used unless space constraints dictate a concrete rectangular vessel. A single stage of carbon treatment should be provided. This may be provided by either a single- or dual-bed vessel, depending on space constraints and cost.

Regardless of configuration, each carbon bed should have downflow air direction to reduce blinding of the carbon support sheet and enable operators to agitate the upper surface of the carbon. Access to the vessels should be via hatches in the side walls and/or dome. Sufficient access should be provided to enable loading by an inclined conveyor with simultaneous manual raking of the carbon.

Vessels shall be structurally and mechanically designed to enable them to be filled with water in case such carbon regeneration is employed.

Design criteria for carbon adsorber vessels are provided in [Table G2-5](#).

Table G2-5. Carbon Adsorber Vessel Design Criteria

Item/Parameter	Criteria
Carbon vessel material	Fiberglass reinforced plastic
Types of carbon	Virgin GAC (nonimpregnated) Impregnated GAC
Sulfide adsorptive capacity	Virgin GAC : 0.02 g H ₂ S/cc Impregnated: 0.14 g H ₂ S/cc
Carbon hardness (ball pan hardness)	90 percent (minimum)
Carbon pore volume (CCl ₄ /100 g)	60 percent (minimum)
Pressure drop across carbon bed	2.0 inches of water column/foot of bed (maximum)
Foul air volumetric loading time	Less than 50 cfm/sq ft (optimum) 60 cfm/sq ft (maximum)
Discharge H ₂ S concentration	1 ppm (maximum)
Air flow direction through carbon bed	Downflow
Empty bed contact time	3 to 4 seconds

Carbon scrubbers have been used in combination with wet scrubbers where the wet scrubber is optimized to remove H₂S while the carbon scrubber utilizes unimpregnated carbon to optimize organic removal. Since carbon is affected by moisture, it is usually necessary to dehumidify the air stream between the wet scrubber and the carbon unit.

G2-6 Plant and Collection System Details

This section describes general information on plant and collection systems, including electrical systems and instrumentation and control systems.

G2-6.1 General

G2-6.1.1 Arrangement of Units and Access

Plant components should be arranged for greatest operating convenience, flexibility, economy, and convenience in installing future units.

Adequate access and removal space should be provided around all components to permit easy maintenance and/or removal and replacement without interfering with the operation of other equipment. Consideration should be given to the need for lifting and handling equipment used in the maintenance and replacement of all components. In addition, the placement of structures and devices such as eyes and hooks used in handling heavy and large components shall be included in the design.

Lines feeding chemicals or process air to basins, wetwells, and tanks should be designed to enable repair or replacement without drainage of the basins, wetwells, or tanks.

G2-6.1.2 Provisions for Flushing, Cleaning, and Draining

Provisions should be made for flushing all scum lines, sludge lines, lime feed and lime sludge lines, and all other lines which are subject to clogging. Flushing can be accomplished using cold water, hot water, steam, and/or air, as appropriate. All piping subject to accumulation of compacted solids shall be arranged to facilitate mechanical cleaning and flushing without causing a violation of effluent limitations and without cross-connecting to the potable water system.

Provisions shall be made for dewatering each unit. The dewatering system should be sized to permit removal of basin contents within 24 hours. Drain lines shall discharge to points within the system so that adequate treatment is provided for the contents of the drained unit. Consideration should be given to the possible need for hydrostatic pressure relief devices. Provision should be made to prevent tank flotation following dewatering. Dewatering pipes should not be less than 4 inches in diameter.

Piping should be sloped and/or have drains (drain plug or valve) at the low points to permit complete draining. Piping should not be installed with isolated pockets that cannot be drained.

G2-6.1.3 Pipe Identification

Pipes should be color coded in a way that will permit ready identification at any location. See [G2-2.8.3](#) for color codes.

G2-6.1.4 Corrosion

Concrete, metals, control and operating equipment, and safety devices should be designed to withstand corrosion.

G2-6.1.5 Operating Equipment

The owner should provide a complete set of tools and accessories for use by plant operators, including squeegees, wrenches, valve keys, rakes, and shovels. A portable pump is desirable. Readily accessible storage space and work bench facilities should be provided.

G2-6.1.6 Facility and Equipment Size and Scale Issues

A. Throttling Valves

The basic valves used for wastewater control are ball, pinch, cone, long radius elbow control valve (designed for sewage), eccentric, and lubricated or nonlubricated plug valves. When considering automatic throttling valves for small plant application, care must be taken not to create a situation that will cause plugging of the valve. Small plants use small lines because the flows are relatively small. The design engineer must ensure that a 3-inch spherical solid can pass through the valve at the lowest desired flow, otherwise plugging can occur.

B. RAS Pumps for Small Plants

When considering centrifugal pumps for RAS pumps in small plants, minimum practical size and revolutions per minute must be taken into account to prevent plugging. The pump must be able to pass a 3-inch spherical solid.

If the pump speed required to produce the desired flow is too low, the pump will plug. The pump impeller then cannot generate enough force and pressure to keep the volute clear of debris and to move a variably viscous RAS along.

Diaphragm pumps should also be considered for RAS pumps for small plants.

C. Aeration Basin Length-to-Width Ratios

The recommended length-to-width ratio for plug flow aeration basins is 40:1. Smaller ratios result in aeration basins which tend to operate more like a complete mix basin. To achieve the required length-to-width ratio in small plants, the basins would be too costly to construct and too narrow to clean. A better solution to achieve plug flow in small facilities is to construct basins in a series with a positive hydraulic grade line between them.

G2-6.2 Mechanical Systems

Screening devices and grit removal facilities are discussed in [Chapter T1](#). Other mechanical system elements such as pumps, blowers, gates, valves, or other mechanical system elements are not addressed in this manual.

G2-6.3 Electrical Systems

G2-6.3.1 General

A. Governmental Codes and Regulations

Sewage treatment system reliability classifications are defined in EPA 430-99-74-001. Plant electrical service shall be as specified by this standard for each reliability class.

Codes and regulations exist at the federal, state, and local level, dictating minimum acceptable requirements for electrical systems. A partial list of codes and regulations to be used as a basis for design is as follows:

- National Electric Code (NEC).
- Occupational Safety and Health Act (OSHA).
- State and local building codes.
- National Electrical Safety Code (NESC).

B. Manufacturer and Technical Society Recommendations

Various manufacturers and technical societies publish standards and recommendations to be used as a basis for design and review whenever the project specifications have not made them mandatory. Those resources include the following:

- National Electrical Manufacturers Association (NEMA).
- Underwriters Laboratories (UL).
- Illuminating Engineering Society (IES).
- Insulated Power Conductor Engineering Association (IPCEA).
- American National Standards Institute (ANSI).
- Institute of Electrical and Electronic Engineers (IEEE).

C. Plan Requirements

Electrical system plans should thoroughly and completely depict the work required. To accomplish the desired results, the electrical plans should include at least the drawings listed here, as follows:

- Electrical legend and general notes.
- Site plan.
- Plant power distribution plan (can be included in site plan).
- Complete electrical one-line diagram.
- Building lighting plans.
- Building power plans.
- Motor control diagrams.
- Equipment and installation details, as required.

G2-6.3.2 Electric Power Sources

A. Reliability

EPA 430-99-74-001 and other reliability criteria dictate whether one or multiple electric supplies are required.

B. Primary Power Source

1. General

Generally, the local electric utility will be the primary source of electrical power. When a second source of electrical power is required, it may be on-site generation or a second connection to the electric utility. If the second source is a connection to the electric utility, it must be so arranged that a failure of one source does not directly affect the other.

2. Service Voltage

The selection of the voltage at which the utility is to serve the plant electrical system is a choice based on several factors, some of which follow:

- The size and arrangement of the plant's electrical distribution system.
- The availability of qualified maintenance personnel for high- or medium-voltage systems.
- Economic advantages that may be built into the electric utility rate schedule which favor taking electrical service at the utilities' distribution voltage.

C. Standby Power Source

The choice between on-site generation versus a second electric utility connection is generally based on cost. Costs to be considered include one-time and monthly electric utility charges, on-site generation-first cost, on-site generation fuel costs, and maintenance costs. In some special cases where the standby power consumption requirements are small enough, portable trailer-mounted engine generators can be used to good advantage by serving as the standby power source for several facilities. Where this option is available, provisions for ready connection to the building switchgear should be made.

G2-6.3.3 Power Distribution Within the Plant

The electrical power distribution system within the plant should be planned and designed on the following basis:

- Plant electrical loads (peak and average demand).
- Maximum fault currents available.
- Proper protective device coordination and device-fault current withstand and interrupt ratings.
- Plant physical size and distribution of electrical loads.
- Plant power factor correction requirements.
- Location of other plant utility systems and facilities.
- Reliability requirements.
- Voltage drop limitations.
- Planned future plant expansions.
- Ability to accommodate upgrades and modifications.
- Feasibility and possible economic justification for electrical demand control system.
- Life-cycle cost of major electrical equipment.
- All codes and regulations, and good engineering practice.

G2-6.3.4 Coordination

Coordination between the electrical plans and the plans and specifications of other disciplines (such as mechanical and structural) must be complete and

accurate. There must also be complete coordination between the electrical plans and specifications. The most frequently found conflicts include:

- Equipment requiring electrical circuits listed in specification sections other than electrical is not shown on the electrical plans.
- Specification requirements for electrical equipment characteristics such as horsepower, voltage, and number of phases differs from characteristics shown on the plans.
- Failure to adequately define and delineate the interface between the electrical system and other systems or contracts.
- Building design doors too small to permit equipment removal.
- Inadequate ventilation for heat generated by electrical equipment.
- Interference between electrical equipment installation and the installation of other equipment or utilities.

G2-6.3.5 Reliability and Maintenance Considerations

A. General

An electrical system must be designed both to be reliable and easily maintained if it is to properly serve its intended purpose. To assist in review of this vital requirement, the following list of frequent design oversights, errors, and omissions has been compiled. This list does not contain any solutions to problems. It is intended only as a reminder to electrical designers or checkers. Solutions to these problems depend on conditions or factors unique to specific projects.

Item	Comment
1. Chemical and electrolytic corrosion, corrosive gases	Chemical and electrolytic corrosion can be a serious problem with direct buried steel conduits and electrical equipment enclosures. Chlorine gas, salt air, and other elements attack exposed conduits.
2. Conduit	Aluminum conduit is incompatible with some types of concrete and earth, and as a general rule should not be embedded in concrete or directly buried in the ground. Consideration for PVC coated rigid steel conduit should be done for these and other corrosive areas.
3. Hazardous areas	Refer to NEC section 500 in toto.
4. Manholes, handholes, and pull boxes	Manholes, handholes, and pull boxes should be provided in raceway systems at close enough intervals to allow pulling cables and conductors without exceeding tension limits. Drainage, pumping, and lighting should be considered.
5. Earth settlement	Earth settlement can cause serious problems with underground raceways, damaging the integrity of the raceway and perhaps the conductors or, by changing the slope of the raceway, upsetting the planned drainage.
6. System capacity	Sufficient system capacity and space should be included in the design to accommodate planned system additions. Some allowance should be made for unplanned system expansion.

B. Lighting Systems

Lighting systems are one of the most visible parts of an electrical system design and therefore one of the most criticized aspects of a design. Some of the more frequent lighting system design problems are as follows:

- Inadequate or too high light levels. (In general, lighting levels should be approximately as recommended in the IES standards.)
- Luminaires difficult or impossible to relamp.
- Improper choice of light source for various occupancies.
- Use of mercury vapor or similar lamps with long startup times in areas not continuously occupied.
- Exclusive use of mercury vapor or similar lamps with a long restrike time following a momentary power failure in rooms that are continuously occupied.
- Light switches trapped behind doors.
- Inadequate emergency lighting.
- Failure to consider efficiency, power factors, noise level, and temperature when specifying ballasts.
- Failure to consider color rendition when specifying lamps.
- Failure to consider third harmonic currents.
- Improperly located luminaires.
- Inadequate light, glare, or shadows.

C. Engine Generators

Engine generators are used with increasing frequency as a standby power source as the reliability requirements of sewage systems become more stringent.

1. Phase Alignment

Care must be taken in the electrical design to ensure that on retransfer from the standby source to the normal source, the motor branch circuit breakers and main circuit breakers are not opened because of out-of-phase relationships between the regenerative motor voltage and the normal supply voltage.

2. Muffling

The proper level of muffling must be specified. Also, the location of exhaust gas discharge must be coordinated with the location of ventilation system air-in openings.

3. Louvers

Electrically operated louvers in engine generator spaces should be of the energized-to-close/deenergized spring-loaded-to-open type.

4. Fuel System

A day tank with an electrical fuel pump should be specified for diesel-fueled units. Control power must be on backup power circuits.

5. Starting

Sufficient delay should be provided in starting the engine generator to allow recloser operation of the utility system. Sufficient delay should be provided on retransfer to the normal source to ensure that the normal source has been firmly reestablished.

6. Switchgear

Whenever possible, plant electrical main switchgear and standby engine generators should be in separate building spaces.

7. System Expansion

Planned system expansion and required standby power requirements should be carefully considered when sizing engine generators.

8. Starting Current

The economics of all of the various methods of reducing the total electric motor starting current requirements should be carefully considered and compared with the costs associated with the different sizes of engine generators which could be utilized. In systems with variable-speed pumping connected to the standby power source, careful consideration of the size of the engine generator specified and the inrush current of the variable-speed system actually furnished on the project is essential.

D. Uninterruptible Power Supplies (UPS)

Uninterruptible power supplies must be considered, sized, and distributed to support a variety of supervisory process controls and to maintain plant operations. Telephone systems, in-plant supervisory control (SCADA or SCS), a variety of plant and network computer systems, and just plain backup power systems require a degree of UPSs to stay on line or in restoration. Plan and appropriately allow for these.

UPSs require special provisions in location, ventilation, maintenance, and interconnection to building and other electrical power and equipment systems. The sizes and locations must be provided for upfront in the design in order to prevent costly provisions in remote siting.

Consideration of the type of UPS to be furnished in particular locations will greatly impact the configuration of the location. In addition, the type of switching options, on-line control operation, and battery backup will determine special needs.

Alarming off-line or trouble conditions of the UPSs should be incorporated into the design. A troubled UPS during a power failure can cause or compound the effects of an outage, and interfere with timely restoration of operations. Advance notice of problems can prevent such occurrences.

E. Ground Fault

1. Ground Fault Sensors

Ground fault sensors are required on services rated 1,000 amps or larger (refer to NEC 230-95). Special attention should be given to the advisory statement contained in the last paragraph of 230-95(b).

2. Switching Equipment

Ensure that all electrical switching equipment is specified with adequate fault current to withstand and interrupt ratings.

3. Grounding Circuits

In general, it is good engineering practice to install a separate equipment grounding conductor in the raceway with the circuit conductors for all circuits where the voltage exceeds 150 volts to ground, and on all circuits rated 60 amps or more, regardless of voltage.

4. Grounding Dual-Fed Services

Particular attention should be paid to the method of grounding dual-fed or double-ended services where ground fault sensors are used (refer to NEC 250-23, exception four). It is good practice to require that connections to grounding electrodes are readily accessible to permit periodic inspection.

F. Parts

1. Standard Parts

Wherever possible, the electrical system should be designed for standard parts and components available from several sources or manufacturers.

2. Replacement Parts

An adequate inventory of spare or replacement parts on-site is vital where maximum operating continuity is important.

G. Flooding

1. Equipment

Wherever possible, electrical equipment should be installed above the maximum flood level. Flooding from any source should be considered, including the possibility of piping or structural failure within the facility (such as a piping failure that could flood the dry pit of a pump station).

2. Conduits

Conduits embedded in the concrete walls of water-holding basins should be above the water surface in the basin to prevent water from entering the raceway at construction joints where expansion joints will be required in the conduit.

H. Miscellaneous

1. Oil-Insulated Equipment

Transformers, switches, and other oil-insulated equipment should be designed with adequate oil retention or containment facilities, in addition to other requirements in the applicable sections of the NEC.

2. Equipment Protection

Generally, centrifuges, fixed-platform aerators, centrifugal compressors, and similar equipment should be provided with vibration detectors. High inertia drives, such as centrifuges, which have long accelerating times, may require special motors, circuit protective devices, and overload relays.

Electrical equipment must be protected from moisture and dirt. In general, major electrical equipment such as switchboards and motor control centers should be installed in a room or space dedicated exclusively to electrical equipment.

3. Restart

Selection of momentary versus maintained contact switches, especially in motor control circuits, needs careful consideration if restart without operator action is desirable or required. If restart without operator action is part of the design, the effect of the total motor-starting current on main and feeder circuit protective devices should be considered.

4. Temperature Detectors

In general, providing temperature detectors embedded in the motor windings for (1) all manually started squirrel cage motors 220 hp and larger and less than 600 volts, and (2) all automatically started squirrel cage motors 100 hp and larger and less than 600 volts, is good engineering practice. Motors above 600 volts, DC motors, synchronous motors, and adjustable-speed drives are usually special cases, and running overload or over-temperature protective schemes should be considered on a case-by-case basis.

5. Aluminum Conductor Substitution

On projects where conductor ampere capacity is based on copper but substitution of aluminum is allowed, a careful review of any proposed substitution of aluminum conductor size and the size of the associated raceway is needed. For some but not all copper conductors, the next larger aluminum conductor will have an equivalent ampere capacity; however, for some copper conductor sizes the aluminum conductor with an equivalent ampere capacity is two sizes larger. Some engineers believe it is good practice to restrict the use of aluminum to conductors size N-2 AWG and larger.

6. Space Requirements

Designers should consider headroom and working space requirements around equipment to meet codes, facilitate maintenance, and permit equipment removal or replacement. Also, variations in dimensions

among equipment made by different manufacturers should be considered.

7. Utility Outlets

The design should ensure that sufficient power outlets of the proper type are provided in the vicinity of process equipment to permit operation of power tools for maintenance.

G2-6.4 Instrumentation and Control Systems

G2-6.4.1 General Requirements

A. Governmental Codes and Regulations

Sewage treatment systems are classified by reliability as required in EPA publication 430-99-74-001. Plant instrumentation and control systems should be designed to comply with the applicable requirements of this standard.

Codes and regulations exist at the federal, state, and local level that dictate minimum acceptable system requirements. The applicable portions of the following partial list of codes and regulations should be used as a basis for design and/or review:

- National Electric Code (NEC).
- State and local building codes.
- Occupational Safety and Health Act (OSHA).

B. Manufacturer and Technical Society Recommendations

Various manufacturers and technical societies also publish standards and recommendations. The following partial list of standards and recommendations should be used as a basis for design or review whenever the project specifications have not made them mandatory:

- Instrument Society of America (ISA).
- Institute of Electrical and Electronic Engineers (IEEE).
- Underwriters Laboratories (UL).

C. Plan Requirements

Instrument and control system plans should thoroughly and completely depict that work. The plans, in conjunction with the specifications, must define the type of control system, the type of components in the system, process variables, scale ranges and set points, process flow rates, and the interface between the instrumentation and control system and the remainder of the plant. To accomplish this, the instrument and control plans should include, as a minimum, the following drawings:

- Instrumentation and control system legend and general notes.
- Process and instrumentation diagram (P&ID).
- Process flow diagram (may be combined in P&ID).

- Plans showing location of all instrument and control system equipment and components and signal circuits, both electrical and pneumatic.
- Switching logic or schematic drawings.
- Equipment and installation details as required.

G2-6.4.2 Instrument and Control System Reliability Requirements

A. General

The size, complexity, and operating requirements of the treatment process are important, but are not the only factors in establishing the instrument and control system type. Compatibility of diverse components has been a consistent problem, so a single manufacturer should be specified whenever possible. Other factors may be cost, required operator skill level, and owner preference. The reliability requirements of the instrument and control system are dictated by the treatment process and the reliability classification, as defined by EPA-430-99-74-001.

The operating reliability of instrument and control systems in sewage plants is determined by the reliability classification and the treatment process. The information necessary to make control decisions should be available from two sources, a primary element and a secondary element; or by inference from one or more process monitors in different but related process areas or zones. Operator intervention/override should be provided for all automated process controls. Effective intervention by an operator requires that process information, such as flow, pressure, levels, and so on be available in a form and location usable by the operator.

B. Design Considerations

The instrumentation and control system within the plant should be planned and designed on the following basis:

- Process operational requirements.
- Control system maintainability.
- Control system stability.
- Planned future plant or process expansion.
- Economic justification of automatic versus manual control.
- Use of standard products wherever possible.
- Need for uninterruptible power supplies to instrumentation and control system.
- Local and/or remote manual controls.
- Process or equipment “fail safe” requirements.
- All applicable codes and regulations, and good engineering practice.

G2-6.4.3 Coordination

Coordination between the instrumentation and control drawings and specifications and the drawings and specifications of the other disciplines

(such as electrical, mechanical, and structural) must be complete and accurate. There must also be complete and accurate coordination between the instrumentation and control system drawings and specifications. A list of the most common conflicts follows:

- Equipment requiring electrical power is not coordinated with electrical drawings.
- Specification requirements for equipment characteristics is different from characteristics shown or implied in drawings.
- Failure to adequately define and delineate the interface between the instrumentation and control system and other systems or contracts.
- Failure to properly coordinate instrumentation and control equipment requirements with building or process equipment design.
- Failure to properly coordinate control strategies and field instrumentation required to support the strategies.

G2-6.4.4 Maintainability—Control Systems

A. Section Summary

Wastewater treatment plants are becoming more dependent on control systems of all types and complexities. Treatment plants are becoming more dependent on the one common feature of control systems: software. Without proper documentation and maintenance of the software, proper operation of the plant is at risk. The operation of a plant relies on proper application programs, which could be lost without adequate system documentation.

System backup programs may also be at risk if system activities such as changes to program logic, changes to the tuning parameters, and changes to the plant (instrument installation) are not properly documented. Maintenance of the control system is difficult if not impossible to accomplish without proper documentation.

B. Identifying the Required Documents

The operation and maintenance of a wastewater treatment plant that uses any type of programmable device for process control requires the following types of documents:

- System description in narrative format.
- System block-diagram drawing that identifies location and node names of the connected PLCs, PCs, operator interfaces, servers, modems, etc.
- Software used for system configuration is always updated and ready to load.
- Drawings showing I/O wiring connections and address assignments.
- Address assignments identifying all of the variables within the control system, such as register and address assignments, variables, and I/O tables (if required).

- Control system programs for each PLC or programmable process control device in a state that is updated and ready to load, as well as a printout of the program.
- Narrative description of each part of the program and the software used to enter the description.

C. Smart Instrumentation

Instruments that provide the control system with both the measurement of the process and diagnostic information about the instrument are referred to as “smart instruments.” Both pieces of information are critical in today’s control systems due to the way data is moved and used. It is common to move analytical data from the control system to a server where many people can view the data and use it in reports. If the instrument is malfunctioning the data may be in error, but it will be used in reports generated from the server. Smart instruments can provide an indication that the quality of the data is in question and therefore reports may not be accurate.

D. PLC Documentation Software

Specifications for wastewater treatment plants using PLCs should include comprehensive requirements for PLC documentation software.

Documentation systems, either from the PLC manufacturer or third-party software vendors, should provide functions important to maintaining a plant such as uploading, verifying, and storing the application programs.

E. Reliability and Maintenance Considerations

An instrumentation and control system must be designed with both operational reliability and maintainability if it is to properly serve its purpose. To assist in review of this vital requirement, the following list of frequent design oversights, errors, and omissions has been compiled. (The list does not contain any solution to problems. It is intended only as a reminder to designers or checkers. Solutions depend on conditions or factors unique to specific projects.)

- Millivolt-level signals inadequately separated or shielded from parallel runs of heavy power circuits.
- Millivolt-level signals not in twisted shielded pair or triad construction.
- Electric and pneumatic signal conductors not in conduit or otherwise protected from physical/mechanical damage.
- 120 vac control circuits too long, allowing distributed capacitance to keep the circuit energized after the primary control element is opened.
- Hazardous area (refer to NEC section 500 in toto).
- Failure to use oil-free air in pneumatic control systems.
- Failure to indicate when single-point grounding is required.
- Failure to indicate or specify required voltage regulation or over-voltage protection.

- Failure to specify adequate equipment enclosures for adverse, hostile, or hazardous environments.
- Failure to consider possible or probable clogging of sensor lines by grease or solids in the process stream.
- Failure to specify or provide isolation valves on instruments connected to process piping.
- Failure to specify snubbers on pressure switches.
- Failure to provide needle valves for control of operating air or hydraulics to control valves.
- Float switches in very turbulent areas.
- Flow meters too close to bends in process pipes.
- Installation of equipment in areas difficult or impossible to reach for maintenance.
- Failure to consider operator convenience in layout or design of control system.
- Failure to provide operator with sufficient process data.

G2-6.4.5 Flexibility—Control Systems

A. Flexibility Issues

The control system should be designed for future growth and expansion.

B. Plant Expansion

As equipment is added to the treatment plant, additional connections to the control system will be required. The future requirements can usually be identified since the mechanical plans normally show future equipment.

G2-6.4.6 Technologies—Control Systems (DCS/SCADA) Design

A. Define the Functional Requirements

The functional requirements should be developed in response to operational requirements identified in meetings and workshops with operations staff.

B. Key Functional Requirements

The DCS/SCADA system should be designed using the control system functional requirements defined in the workshops with the operational staff. Some of the key functions required for a DCS/SCADA system include:

- Redundancy of the DPU/PLC hardware configurations and failover sequences of the process control software and operator interfaces.
- Coordination of the PLC and DCS/SCADA programs.
- Global database management.
- Ability to manage the total number of I/O tags.
- Data integrity and scanning processes used to acquire data.

- Historical database management.
- Control system response time.
- Data highway topologies including redundancy and self-healing capabilities.

C. Coordinated and Integrated Software Functions

The software that will provide the operator interface and data management, including trending and historical functions, must have a high level of continuity between the DCS/SCADA functions and field hardware.

D. Historical Database Management

Wastewater treatment plants require data to be gathered, stored, trended, and archived.

DCS/SCADA system hardware should provide historical information processing and trending.

The ability to export data to other software systems will provide the historical archiving and trending functions required by the wastewater treatment plant. The capabilities of the software vendors' historical and trending functions should be a high-priority selection criteria.

E. The Operator/Management Interface

Avoid using graphics as the main factor in selecting control system software; all software vendors have great graphics. Wastewater treatment plants operate on trends and history more than immediate existing conditions.

How trends, reports, and historical information is presented to the operators and plant management is one of the key elements that defines the control system's computer platform.

How displays are developed for the graphic user interface is an important design consideration. Operator input should be solicited during the design.

F. Moving Data to Other Systems

It is common to find process control data moving to/from other computer systems. This may include laboratory information management systems and maintenance management systems. The data that moves between the systems must be in a standard format that can be used by both the control system and these information management systems.

G2-6.4.7 Coordination with Process Design

A. Section Summary

The coordination between the control systems, instrumentation, and control systems is imperative for proper process control.

B. Design Coordination

If a control system is used the coordination must extend to the development of the control system. Data bases must be coordinated to

ensure installed instruments are connected to the control system and the signals are properly noted and stored. Graphic images must be developed for the operator's workstation or PC and must utilize the instrumentation data and the processes piping at the plant. The graphics must tightly link to all instrumentation data and control actuators within the plan. The combination of information and control must provide the operators with the controls to run the plant.

C. The Role of P&IDs

Process and instrumentation drawings (P&IDs) are the single most important part of any drawing package for defining and organizing a project, and understanding how the plant is controlled after the project is completed. Standard ISA conventions should be used.

D. Typical P&ID

The instrumentation and I/O point identification system should follow ISA standards S5.1 Table 1 as much as possible.

The P&ID symbols should be based on standard ISA symbols as defined in Volume I, S5.1 of the Standards and Practices for Instrumentation.

G2-7 Safety

This manual is not intended to serve as a safety manual. Material provided in this section is provided as general information intended to be helpful in achieving a safe workplace for construction of wastewater collection and treatment facilities. Compliance with all federal and state safety regulations referenced in [G2-7.1](#) is required as described in that section.

G2-7.1 Safety Regulations

G2-7.1.1 Federal Regulations

The US Department of Labor's Occupational Safety and Health Act (OSHA) federal safety regulations cover all wastewater collection, conveyance, and treatment activities. OSHA enforces these regulations through CFR 29 1910. Individual states with federally approved industrial safety programs (such as Washington State) may also enforce these standards.

G2-7.1.2 Washington State Safety Regulations

State safety regulations specifically require compliance for all wastewater collection, conveyance, and treatment plant operation, maintenance, and construction activities conducted in the State of Washington. WISHA enforces these regulations through the following codes:

- Chapter 296-24 WAC, General Safety and Health Standards.
- Chapter 296-62 WAC, Occupational Health and Safety.
- Chapter 296-67 WAC, Process Safety Management.

Other regulations enforced by WISHA that may directly apply to the design and construction of wastewater collection, conveyance, and treatment industry structures and facilities are as follows:

- Chapter 296-37 WAC, Commercial Diving Operations Safety.
- Chapter 296-44 WAC, Electrical Construction Safety Code.
- Chapter 296-45 WAC, Electrical Workers Safety Rules.
- Chapter 296-65 WAC, Asbestos Removal and Encapsulation Safety.
- Chapter 296-155 WAC, Safety Standards for Construction Work.
- Chapter 296-306 WAC, Agricultural Safety Code (Biosolids Application).

G2-7.2 Engineering, Design, and Construction Safety

Engineering, design, and construction safety should not be considered as an option or an add-on feature applied after construction begins or an employee accident has occurred. Construction safety requirements and considerations should be included in the contract documents, including providing for construction safety communication, training, inspection, and monitoring. Clear lines of communication and coordination with the construction contractors and subcontractors is a critically important part of ensuring that proper safety considerations are addressed. Safety considerations should be specifically emphasized during all phases of a project: engineering, design, bid specifications, prebid meetings, preconstruction meetings, and project safety coordination and monitoring.

G2-7.2.1 Contracts

Construction contracts for wastewater collection, conveyance, and treatment structures should identify specific requirements for safety program requirements, submittals, and project-specific safety planning detail.

G2-7.2.2 Prebid Specifications

Prebid specifications should specifically include relevant safety requirements and considerations. Therefore, specifications require the contractor to comply with all applicable federal, state, and local safety regulations as well as site-specific detail and instruction about project safety requirements. In addition, copies of the contractor's safety program should be reviewed by the owner as part of the required project submittals.

Prebid safety and hazardous material compliance specifications are effectively used to inform the contractor of safety hazards and/or priority safety requirements. These might include, but are not limited to, the following:

- Control of physical hazards associated with the project site and construction activities.
- Coordination of vehicle traffic and heavy equipment operations.
- Hazards communication: chemicals used (such as chlorine, sulfur dioxide, lime, ferric chloride, and polymers), biological hazards, and so on.
- Hazardous energy control procedures (lockout-tagout procedures).
- Emergency response procedures and requirements.

- Permit-required confined-space entry procedures.
- Process safety management program requirements.
- Unusual process operations, such as the use of pure oxygen, or advanced technology pilot projects.
- Biosolids handling facilities.
- Availability of fire or rescue personnel.
- Other hazards as appropriate.

Informing the general contractor and subcontractors of these exposures is specifically required under various safety regulations and offers many advantages toward ensuring safety and environmental compliance. Such information enables the contractor to protect employees, construction inspectors, and the public.

G2-7.2.3 Preconstruction Meetings

Preconstruction meetings offer an opportunity to reemphasize safety requirements and considerations necessary during the project. Emphasizing safety at preconstruction meetings demonstrates the concern for employee safety and provides documentation of the safety information available.

G2-7.3 General Wastewater Safety Hazards

The environment of a wastewater collection, conveyance, and treatment system may present many potential hazards as a result of the nature of wastewater and its byproducts as well as the treatment processes, chemicals, and equipment. A composite list of potential hazards and hazardous areas that should be considered by engineers, designers, and the project manager follows. (The following safety considerations are intended to stimulate thinking rather than serve as a comprehensive checklist. Many items may not directly apply to all wastewater facilities.)

<ul style="list-style-type: none"> • Abnormal atmospheres (ammonia, carbon dioxide, carbon monoxide, chlorine, ethane, gasoline, hydrogen chloride, hydrogen sulfide, methane, mixture of gases, natural gas, nitrogen, oxygen-deficient environments, oxygen-rich environments, ozone, polymers, sewer gas, sludge gas, sulfur dioxide, and temperature extremes). • Airborne hazards (bioaerosols, biological agents, chemical dust, dust, mists, fumes, toxic or explosive gases, and volatile solids). • Backflow prevention. • Burns (chemical and thermal). • Chemicals (corrosives, oxidizers, flammable, toxic, reactives, unstable, etc.). • Confined spaces. • Drowning. • Earthquakes. • Electrical bonding and grounding. • Electrical shock. • Elevated work spaces or working platforms. • Explosive gases or liquids. • Falls. 	<ul style="list-style-type: none"> • Fires. • Flooding. • Food contamination. • Housekeeping (internal and external). • Impact. • Infections and diseases. • Ingress and egress (entrances and exits). • Laboratory. • Ladders, stairs, and ramps. • Landscaping and landscape maintenance. • Lifting (ergonomics). • Lightning protection grounding. • Materials handling and material movement. • Moving machinery and machine guarding. • Natural hazards (lighting and flood protection). • Night operations and essential lighting. • Noise. • Noxious gases and vapors. • Openings. • Open tanks.
--	---

<ul style="list-style-type: none"> • Overhead fixtures. • Overflow drainage. • Pinning and crushing. • Slips, trips, and falls. • Spillage. 	<ul style="list-style-type: none"> • Vapors and dust (gasoline, solvents, dried sludge, activated carbon, etc.). • Vehicles and traffic control. • Ventilation. • Walkways. • Weather (heat, cold, ice, and snow).
--	---

G2-7.4 Hazardous Materials and Chemical Handling

The many types of hazardous materials, chemicals, solvents, and fuels stored at wastewater facilities for a variety of uses may pose a potential health hazard in normal use or accidents.

Common uses of hazardous materials and chemicals at wastewater facilities include wastewater facility processes, process control, housekeeping, landscaping, laboratory, maintenance, fuels, and odor control. In addition, material safety data sheets provided by chemical manufacturers describe proper handling of chemicals.

Hazardous materials that become wastes are considered hazardous wastes and need to be handled and disposed of properly.

Commonly used hazardous materials in wastewater facilities include, but are not limited to, the following items.

Treatment Chemicals	Combustible, Flammables and Explosive Hazards
Alum Ammonia Caustic Chlorine Chlorine dioxide Defoamers Ferric chloride Ferric sulfate Hydrochloric acid Hydrogen peroxide Lime Odor-masking agents Oxygen Ozone Pesticides Polymers Sodium bisulfate Sodium hypochlorite Sodium thiosulfate Sulfuric acid Sulfur dioxide	Activated carbon Acetylene Diesel fuel Digester gas Fuel oil Gasoline LP gas Lubricating oils Welding gases Methanol LP gas Paints and thinners Solvents

These additional safety considerations should also be thoroughly reviewed prior to the design and construction of wastewater facilities that will house hazardous materials.

(The following safety considerations are intended to stimulate thought and consideration—rather than serve as a comprehensive regulatory compliance checklist. Many items may not directly apply to all wastewater facilities.)

<ul style="list-style-type: none"> • Compliance with storage and handling requirements per local fire codes and the UFC. • Well lighted unloading facilities that are easily accessible by emergency response crews. • Unloading station clearly marked. • Unloading facilities well ventilated for delivery vehicle exhaust emissions. • Separate receiving and storage areas for chemicals that react violently if mixed together. • Temperature controlled storage. • Ventilation provided. • Containers shielded from heat sources. • Leak detection provided. • Leak repair kits provided. • Vacuum relief devices on tanks. • Tank liquid-level measuring devices and alarms provided. • Pull-chain or pedal-operated deluge showers with pedal-operated, chest-level-high wash spouts and a floor drain adjacent to areas where hazardous chemicals are being handled or stored (alarm when used). • Guard posts for equipment and storage tanks, including underground tanks to prevent damage by vehicles (fire codes often include specific requirements for post type and location). • Seismic restraints on gas cylinders. • Fuel gas cylinders separated from oxygen cylinders. • Ventilation exhaust ports adequately dispersed and located such that discharges will not contaminate air inlets in other areas. • Treatment systems for hazardous gas releases. • Repair and containment kits for cylinders and tanks. • Light and ventilation switches located outside. • Self-contained breathing apparatus provided. • An automatic control to actuate forced ventilation and lighting when chemical rooms are occupied. • Approved storage for flammables, thinners, solvents, etc. 	<ul style="list-style-type: none"> • Additional storage space for peak storage demands. • Dikes or curbs capable of holding the stored volume, plus a safety allowance in each liquid chemical storage area (designed to allow chemicals to be recovered and reused). • Health risks associated with chemicals considered (refer to chemical material safety data sheets). • Piping minimized. • Pumping and piping systems permanently installed for delivering liquid ferric chloride, sulfuric acid, and other corrosive liquid chemicals to the application point. • Chemical pressure piping systems provided with pressure relief to storage areas. • Chemical storage areas sited to eliminate the need to reach beyond safe handling limits. • Nonslip floor surfaces in areas where polymers may be spilled. • Dust collectors provided on chemical elevators. • Materials and devices used for storing, transporting, or mixing hazardous chemicals compatible with the chemicals involved. • Tanks, bins, and other containers labeled. • Chemical material safety data sheets provided. • Separate chlorinator/chlorine evaporator and chlorine storage rooms, each with aboveground ventilation only to outside air. • Chlorination facilities with concrete floors and adequate but separate drainage from other facilities. • View windows to the chlorinator/chlorine evaporator room and chlorine storage room for outside observation. • Chlorine leak detection devices provided. • Chlorine leak containment system to capture and neutralize released chlorine (for large systems). • Liquid chlorine containers stored in well-ventilated, fireproof structures with protection against direct exposure to the sun. • Spill Response and Leak test kit. • Dry hypochlorite stored in a cool, dry area.
---	--

G2-7.5 Walking and Working Surfaces

The many types of potential hazards associated with walking and working spaces may pose a potential risk to the health and safety of employees during the course of routine work activities.

Consideration of safe walking and working surfaces should be thoroughly reviewed prior to the design and construction of wastewater facilities. (The safety considerations in the tables below are intended to stimulate thinking rather than serve as a comprehensive checklist. Some items may not directly apply to all wastewater facilities.)

General Work Area Considerations	<ul style="list-style-type: none"> • An open channel immediately ahead of the point where wastewater enters the influent structure to vent explosive gases and vapors. • Wetwells located in a separate structure or accessible only from the outside, and properly ventilated. • Monitored and alarmed screen room or shredder room, separated from other facilities, with clear access to the outside. • Protection against flooding, including alarms as appropriate. • Equipment, piping, valves, and other appurtenances within structures arranged for ease of access and ample space, including headroom and walk aisles. • Work platforms for elevated equipment that may require adjustments, observations, or preventive maintenance. • Access to windows, lights, HVAC, odor control filters, and ceiling-mounted items that must be operated or maintained. • Adequate space and access for equipment repair or removal. • Adequate space for equipment storage. • Dual entrances or accesses to potentially hazardous areas with tight-fitting, self-closing doors that open outward and are equipped with panic hardware. • Panic hardware on exit doors and fusible links on doors in high fire-risk areas, as appropriate. • Potentially explosive areas provided with explosion venting, protective devices, suppression systems, or barricades. • Equipment maintenance shops with appropriate safety provisions for hazards associated with maintenance activities. • Nonslip surfaces (such as broom-finished concrete or nonslip covering) for floors and ramps. • Dust accumulation spots minimized (open truss members, ledges, light fixtures, etc.). • Laboratories with two easily accessible exits that are reasonably remote from each other. • Designed to withstand earthquake forces. • Basement areas with two easily accessible exits that are remote from each other. • Light interior colors in dim areas. • Provisions for the safe collection of samples. • Interior doors, where appropriate, that swing both ways and have see-through panels. • Lightning protection. • Adequate climate control (humidity, temperature, and so on) for comfort in offices, laboratories, eating areas, work stations, and selected work areas. • Walking aisles and machine areas identified. • Allowable floor loadings posted.
---	--

Walkways, Ladders, Stairways, and Ramps	<ul style="list-style-type: none"> • In nonhazardous areas, manhole steps or permanently attached ladders inside tanks, basins, or wetwells for entry or exit in case of emergency. • Fixed ladder systems must have 36-inch minimum walkthroughs at the top of the ladders to allow continuous employee fall protection support. • Fall protection anchorage points provided for potential work spaces with fall hazards greater than 10 feet. • Nonslip stair treads on landings and stairs. • Stair risers of equal height and proper slope per regulatory specifications. • Standard handrails (36- to 42-inch minimum) and midrails (18 to 21 inches) of type and cross-section such that they can be fully gripped with fingers and thumb. • Separate handrail to provide a handhold where entrance is provided by ship's ladders or entrance level. • Fixed ladders more than 20 feet long equipped with safety cages, ladder safety devices, or fall protection systems. • Fixed ladder systems greater than 30 feet must be provided with rest or offset landings. • Rest landings on stairways. • No manhole steps or fixed ladders to provide access to hazardous areas. • Ramps with slopes commensurate with intended use and provisions to prevent slips, trips, and falls. • In climates with ice and snow, gratings on outside stairs and walkways on tanks wherever possible. • Lift-rings and grating locks flush-mounted to prevent tripping.
Openings and Hatchways	<ul style="list-style-type: none"> • Railings designed to withstand 200 pounds loading with kickplates around openings and stairwells. • Hatchway covers with springs or positive locking devices to hold the covers open (unless they swing free of opening and lie flat). • Double handrails, fencing, or guards of proper height at floor and wall openings, pump wells, influent structures, open tanks, and aboveground ramps.
Fall Protection	<ul style="list-style-type: none"> • Designs for new or renovated facilities should consider and eliminate potential fall hazards for operations, maintenance, and contractor personnel. • Work performed on unprotected walking/working surfaces more than 10 feet from a lower level requires use of fall protection systems. • Walkways greater than 4 feet in elevation above an adjacent exposed level require standard handrail protection. • Fall protection anchorage points are secure structures that can withstand forces exerted by fall arrest and rescue equipment. This can include a beam, girder, column, or floor. The minimum strength requirement is 5,000 pounds. Improvised anchorages must be unquestionably strong and used with certified anchorage connectors.

G2-7.6 Working Spaces

Design, engineering, and construction of wastewater facilities that will provide working spaces for employees should incorporate appropriate considerations of HVAC systems, potable water supply, personal hygiene facilities, adequate lighting, first aid, housekeeping, and noise control. The following considerations should be reviewed and considered for design, engineering, and construction of these facilities. (The following safety considerations are intended to stimulate thinking rather than serve as a comprehensive checklist. Many items may not directly apply to all wastewater facilities.)

Ventilation Considerations	<ul style="list-style-type: none"> • Separate, mechanical, forced ventilation for spaces such as influent channels, influent rooms, wetwells, dry wells, screen rooms, shredder rooms, grit chambers, disinfection areas, manholes, sumps, pits, sludge pump areas, sludge storage areas, sludge digestion areas, gas control rooms, sludge storage and conditioning tanks, centrifuges, sludge-processing areas, digester buildings, boiler rooms, engine rooms, incinerator rooms, laboratories, garages, maintenance shops, laundry rooms, and shower rooms (even belowground structures without a cover are hazardous; natural ventilation that is inadequate under some conditions has caused fatalities). • Ventilation to force fresh air into wetwells so that the exhaust ventilator does not pull sewer gases from the influent sewer into the wetwell. • Forced mechanical ventilation automatically actuated when chlorination rooms, chemical handling rooms, and laboratories are occupied. • Critical ventilation sustained during emergencies such as floods, fires, storms, or power failures (fire code may require break-glass-type emergency shutoff for hazardous materials locations). • Ventilation exhaust ports adequately dispersed and located to discharge where there will be no contamination of air intakes. • Adequate provision for makeup air for ventilators. • Treatment of hazardous materials in ventilation exhaust (required by some fire codes). <p>(Note that ventilation which is adequate for control of fire and explosion might be insufficient for health protection.)</p>
Water Supply	<ul style="list-style-type: none"> • Potable water (when used for plant processes or other purposes such as washdown of equipment) must be protected by backflow preventers, vacuum breakers, or airbreak. Includes all washdown hoses, pump seals, and so on (backflow preventer provided in the plant supply). • Warning signs near each nonpotable water outlet; color coded, nonpotable water lines. • Adequate supply for fire protection. • Adequate pressure to hoses for cleanup (excessive pressure can be a hazard). • See G2-2.2 and C2-2.1.2 for additional information on water supply.
Personal Hygiene Facility	<ul style="list-style-type: none"> • Walk-through shower facilities with hot and cold running water. • Two lockers for each employee, one for work clothes and another for street clothes. • Washing machine and dryer for work clothes. • Pedal-operated laboratory sinks, toilets, and wash sinks. • Disinfectant dispensers, liquid soap dispensers, and towel dispensers.

Lighting and Work Space Illumination	<ul style="list-style-type: none"> • Adequate exterior and interior lighting throughout the plant, particularly in areas of activities such as repair and servicing of equipment, valves, and controls. • Lights that promptly illuminate hazardous and interior areas. • Emergency lighting (battery-operated lights) and exit lights for interior areas, particularly in the vicinity of stairways. • Portable, explosion-proof lighting system. • Emergency generator set. • Lighting of warning signs.
First Aid	<ul style="list-style-type: none"> • First aid supplies or kits. (Under some conditions, OSHA requires approval by a consulting physician.) • Posted instructions for calling 911 and/or emergency medical services.
Housekeeping	<ul style="list-style-type: none"> • Ample storage areas for equipment. • Hose bibs, hoses, nozzles, and hose racks in spillage areas. • Water-repellent wall surfaces for cleanup purposes. • Sludge pumps with quick-closing sampling valves. • Floors sloped and drained to facilitate cleaning. • Cleaning equipment, including industrial vacuum cleaners, brooms, mops, high-pressure washer, steam cleaners, etc. • Splash guards and drip pans. • Airtight, metal receptacles for solvent soaked and combustible wastes. • Seal water discharged to hub drains adjacent to or integral to the equipment.
Noise Control Considerations	<ul style="list-style-type: none"> • Equipment designed for noise reduction below 85 decibels. • Provisions for reducing noise from multiple equipment units (enclosures). • A maximum permissible noise level during operation, expressed in decibels of sound under standard test conditions. • Air compressors, vacuum pumps for filter units, centrifuges, blowers, standby power units, and other similar equipment producing high noise levels located either within isolated buildings or rooms or within acoustically sound-proofed structures for maximum sound reduction.
Odor Control Systems	<p>Odor control systems, increasingly common in treatment facilities, may present several hazards. Major elements of these systems are typically a collection structure, a cover over basins of wastewater or sludge, ducts, contact vessels, chemical makeup and feed systems, chemical piping, chemical solution recycle, blowers, and discharge stacks. Because these systems collect gases that could be explosive or toxic, they need to be carefully designed to avoid release of the collected gases into an operating space. The design of these systems should include monitoring for combustible or toxic gases.</p> <p>Individual elements within odor control systems, such as covered channels or basins, large ducts, contact vessels, etc., may be considered as "confined spaces" as described in G2-7.8.</p>

G2-7.7 Fall Protection and Prevention Systems

Industrial safety controls that are designed, engineered, and constructed for wastewater treatment facilities include the following:

Piping and Valve Installation Considerations	<ul style="list-style-type: none"> • Valves are accessible and easily operated. • Large, frequently operated valves are power operated. • Head clearance is provided. • Valves located above reach are chain or power operated. • Influent and discharge pipes to pumps and other equipment are valved so that dismantling them will not result in wastewater, sludge, gas, or chemicals entering the work area. • Piping will not block or restrict access for routine operation or maintenance. • Selected valves are provided with lock devices. • Freeze protection is ensured. • Supports are required when systems are dismantled for maintenance. • Sludge pumps are equipped with pressure gauges to indicate gas buildup when pumps are out of service. • Safety and relief devices are provided on heat exchangers. • Cages or guards around accessible hot piping. • Stubouts for future construction are designed so they are not a hazard. • Safety guards located around check valve exterior levers. • Standard color-coded process piping and emergency equipment. See G2-2.8.3.
Gas Monitoring Device and Alarm Installation	<ul style="list-style-type: none"> • Alarm systems, both visual and audible, to detect explosive or combustible gases and vapors in screenings of shredder rooms, digester areas, flammables storage, tunnels, galleries, and elsewhere, as needed. • Sensing devices equipped with visual and audible alarms both nearby and at a central location, placed in all hazardous areas for combustible or explosive gases and vapors. • Oxygen leakage detectors at appropriate points on oxygen supply tanks. • Chlorine leak-detection devices to signal equipment failure in larger installations. • Visual and audible alarms.
Incinerator Installation	<ul style="list-style-type: none"> • Dry sludge handling methods to preclude dust accumulation that results in potential dust explosion. • Automatic signal for incinerator flame-out. • Automatic shutdown controls in the event of incinerator flame-outs. • Fully automatic ignition start controls. • A proper safety train on the incoming fuel supply of the auxiliary fuel system. • Burner system controls to ensure adequate purge time, including interrupted pilot, flame scanner, and safety controls to prevent the possible lighting or relighting of a burner in a potentially hazardous atmosphere. • Adequate temperature controls. • Adequate ventilation.

Laboratory Safety	<ul style="list-style-type: none"> • Durable, nonslip floor material. • Ventilation with adequate makeup air, explosion-proof motors, and laboratory hoods in special test areas. • Eye wash and deluge shower. • Clearly identified gas outlets equipped with substantial handles. • Lips on storage shelves for earthquake protection.
Maintenance Shop Safety	<ul style="list-style-type: none"> • Provisions for protection against infrared radiation from combustion units, ultraviolet radiation from arc welding, etc. • Exhaust facilities for welding and grinding. • Enclosure and ventilation for sand blasting, solvent cleaning, and spray painting areas. • Adequate materials handling equipment, including cranes and hoists.
Materials Handling and Storage Safety	<ul style="list-style-type: none"> • Chemical storage areas located so personnel do not have to stretch beyond safe handling limits. • Provisions for keeping manual lifting to a minimum. • Provisions for using hand trucks. • Access to storage shelves for power lifting equipment. • Well planned, safe operations associated with railroad cars, including provision of derailleurs and wheel chocks. • Fixed or portable electrical hoists with ceiling lifting devices for lifting heavy loads, including chemicals, pumps, motors, and equipment for repair or replacement. • Hoists to remove and lower equipment into pit areas. • Dust collectors on chemical elevators at loading points. • Drum handling equipment. • Rigging materials (ropes, chains, hooks, devices, pins, etc.) rated for intended service. • Restraints on gas cylinders. • Provisions for earthquake forces, as necessary. • Safety equipment, including portable ventilation equipment such as air blowers and adequate lengths of noncollapsible ducting, indicators for hydrogen sulfide, combustible gases, methane, chlorine, carbon monoxide, and oxygen deficiency; proper self-contained air breathing apparatus; inhalators; resuscitators; decibel meter noise analyzers; explosion-proof flashlights; portable lifting equipment; first aid kits; safety tools (nonsparking); and nonconducting ladders with nonskid feet. • Safety harnesses, ropes, tripods, and hoists for entering vaults or pits containing potentially harmful or explosive gases. • Safety poles, life preservers, life jackets, or combinations of these at needed locations. • Fire extinguishers. • Barricades, traffic cones, warning signs, flashers, and reflective vests. • Telephones, intercom systems, and two-way radios for communication. • Safety libraries. • Training rooms and training equipment.

Site Layout and Security	<ul style="list-style-type: none"> • Fencing around plant structures, railing, walls, locked doors, etc. where unauthorized entry could result in personal mishap or disruption of plant operations (avoid trapping personnel with these security measures). • Secured entrance gates. • Provisions for emergency vehicles (work closely with the local fire department). • Traffic control signs or signals. • Sidewalks located for natural access routes. • Delineated crosswalks and walkways visible to vehicle occupants and pedestrians. • Landscaping that minimizes the need to use hand-operated mowers, hedge clippers, etc. • Safe landscaping maintenance equipment and associated personal safety equipment. • Landscaping that avoids steep slopes which must be mowed. • Landscaping that does not attract bees and dangerous pests. • Layout that allows sun or heat ducts to melt ice and snow from walks and driveways. • Areas for snow storage. • Containers for storage of sand, salt, or other ice-melting chemicals. • Signs to direct visitors to parking and reception areas to limit wandering by visitors. • Designated parking for visitors and staff. • Provisions for safe transport of chemicals, fuel supplies, sludge, etc.
Safety Signage and Markings	<ul style="list-style-type: none"> • Directive signs, such as "No Smoking," "Safety Glasses Required," "Wear Life Vest," "Hard Hat Required," "Hearing Protection Required," "Danger—Confined Space," "Safety Glasses Required," etc. • Hazard identification signs indicating dangers such as explosive gases, noise, chemicals, flammables, ice, slippery floors, high pressure vessels, high pressure pipes, overhead utilities, and underground utilities. • Instructional signs to indicate correct procedures in critical locations and for critical operations or emergencies. • Signs to limit or restrict access. • Special equipment bracing where required. • Analysis of items such as piping and storage tanks for seismic loads. • Wind socks and/or wind vanes.
Rotating/Reciprocating Machinery and Machine Guarding	<ul style="list-style-type: none"> • Caps or guards around exposed rotating shafts and all other moving parts (open-mesh type allows equipment viewing without removing guards). • Guards that are easily replaced and fastened. • Guards around long, exposed shafts to safeguard the worker from contact or injury from whipping if the shaft breaks. • Shafts with painted spirals or other markings to indicate running conditions. • Positive displacement pumps with an air chamber and a pressure switch that will stop the pump at a preset pressure. • Nonsparking pulleys, belts, and fan wheels used in explosive areas. • Warning signs on equipment that starts automatically or from a remote location. • Provisions for local disconnects and lockout-tagout receptacles.

G2-7.8 Confined Spaces

Confined spaces are a major cause of death and serious injury in the workplace. The National Institute of Occupational Safety and Health (NIOSH) publishes guides and criteria for working in confined spaces. Confined spaces are defined by OSHA & WISHA regulatory codes and NIOSH publications as “any space which by design, (1) is large enough for an employee to enter, (2) has limited means for entry and exit, and (3) is not designed for continuous employee occupancy.” Permit-required confined spaces are those confined spaces that contain or have the potential to contain one or more of the following hazards:

- Contains or has the potential to contain a hazardous atmosphere.
- Contains a material that has the potential for engulfing an entrant.
- Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety hazard.

Specific examples of confined spaces in wastewater facilities are as follows:

<ul style="list-style-type: none"> • Manholes (wastewater, stormwater, etc.). • Large pipes and conduits. • Channels. • Tunnels. • Digesters. • Scum pits. • Wetwells. • Dry wells. • Vaults (electrical, valve vaults, and so on). • Grit chambers. 	<ul style="list-style-type: none"> • Screening pits. • Storage tanks and hoppers (chemicals, screenings, water, fuel, sludge, etc.). • Septic tanks. • Septage receiving tanks and pits. • Sumps. • Gas holders. • Excavated holes. • Covered basins and channels. • Odor control systems.
--	---

G2-7.9 Fire Control and Protection Systems

Specific examples of fire control and protection systems include the following:

General	<ul style="list-style-type: none"> • Fire hydrants that meet local fire codes for type and location. • Landscaping that will not result in large quantities of combustible vegetation, particularly near structures. • Smoke and fire alarms. • External fire alarms as required by local fire code. • Automatic fire suppression systems. • Firefighting devices located in each separate structure at accessible points near the entrance to areas of likely conflagration. • Fire extinguishers suitable for the area and the equipment to be protected. • Laboratory wall surfaces, ceilings, and furniture made of nonflammable or fire-resistant materials. • Critical drains sized for fire flows. • Containment for hazardous materials, fire flow, and precipitation.
----------------	--

General (continued)	<ul style="list-style-type: none"> • Provisions to allow use of adequately treated wastewater as a backup firefighting supply. • Equipment, buildings, and fire alarm systems in compliance with local, state, and national fire codes and OSHA and insurance company requirements.
Fuel Storage	<ul style="list-style-type: none"> • Separate storage for gasoline, diesel fuel, digester gas, liquid fuels, and propane. • Containment for spills and overflows. • Floor drain traps for fuel spills.
Gas Collection, Piping, and Appurtenances	<ul style="list-style-type: none"> • Gas protective devices in accordance with manufacturers' recommendations. • Gas piping and pressure-vacuum relief valves on digesters with adequate flame traps. • Drip traps designed to prevent release of gas. • Waste burners and vents located a safe distance from buildings. • Bypasses and valves to allow maintenance of gas equipment. • Ventilated rooms for gas-burning equipment such as boilers and engines. • Automatic shutdown of gas systems at preset pressures.

G2-7.10 Electrical Safety

Specific examples of electrical safety include the following:

<ul style="list-style-type: none"> • Medium and high voltage cables completely enclosed in either conduit or covered trays and adequately marked to warn personnel of contents. • Switchboards with "dead front" and "dead rear." • Moisture-proof enclosures for switches, equipment, and lights in moist areas where there is no possibility of flammable gas accumulation. • Ground fault circuit interrupters where required. • Electrical equipment adequately grounded. • Ground equipment to avoid static electricity sparks in explosive areas. • Ground straps for portable equipment. • Wiring properly insulated, grounded, and nonexposed. • Required clearances provided around electrical equipment. • Electrical "lockout" facilities with padlocks and tags to prevent accidental starts when machinery and equipment are being worked on or otherwise taken out of service. 	<ul style="list-style-type: none"> • Emergency shutoff switch, clearly labeled, at all machinery units. • Oil-filled submersible motors equipped with thermal detectors to deenergize the motor before the ignition temperature of the oil is reached. • Alternative power supply for critical lighting, ventilation, and sensory devices and alarms. • Two separate power sources to the plant, or standby power to keep critical systems operational. • Exterior floodlighting to provide for nighttime operation, maintenance, and inspection. • Safe access for lamp replacement. • Insulating floor mats at control centers and panels. • Maintenance tools with insulated handles and flashlights with nonconductive cases. • Electrical tools (drills, saws, etc.) grounded or double-insulated. • Grounded extension cords. • For future construction, stub-outs designed so they are not a hazard.
--	--

G2-7.11 Process Safety Management and Risk Management Planning

G2-7.11.1 Process Safety Management

Employees have been and continue to be exposed to the hazards of toxicity, fires, and explosions from catastrophic releases of highly hazardous chemicals in their workplaces. The OSHA/ WISHA Process Safety Management (PSM) of Highly Hazardous Chemicals regulation contains requirements for the management of hazards associated with processes using highly hazardous chemicals such as chlorine and sulfur dioxide. It establishes procedures for process safety management that will protect employees by preventing or minimizing the consequences of chemical accidents involving highly hazardous chemicals.

PSM program development specifically includes components required by OSHA's Process Safety Management regulation, as follows:

(A) Employee Participation	(I) Mechanical Integrity Review
(B) Process Safety Information	(J) Quality Assurance
(C) Process Hazard Analysis	(K) Hot Work Permit
(D) Operating Procedures	(L) Management of Change
(E) Emergency Operations	(M) Incident investigation
(F) Employee Training	(N) Emergency Planning and Response
(G) Contractors	(O) Compliance Audits
(H) Prestartup Safety Review	(P) Trade Secrets

G2-7.11.2 Risk Management Planning

The Clean Air Act (CAA) section 112 (r) requires publicly owned treatment plants to implement Risk Management Planning programs to prevent accidental releases of regulated substances (such as chlorine, sulfur dioxide, methane, propane, etc.) and reduce the severity of those releases that do occur. EPA has promulgated regulations that apply to all stationary sources with processes that contain threshold quantities of regulated substances. Processes are divided into three categories based on the potential for offsite consequences associated with: a worst-case accidental release; accident history; or compliance with the prevention requirements under the OSHA/ WISHA Process Safety Management (PSM) Standard. Processes that have no potential impact on the public in the case of an accidental release will have minimal requirements. For other processes, sources are required to implement formal hazard assessments of chemical systems and implement a comprehensive risk management program to prevent a chemical release that would impact the surrounding communities.

Processes in industry categories with a history of accidental releases and processes already complying with the OSHA/WISHA Process Safety Management Standard are subject to a prevention program that is identical to parallel elements of the OSHA/ WISHA standard. All other processes will be subject to streamlined prevention requirements. All regulated facilities must prepare a risk management plan based on the risk management programs established at the source. The source must submit the plan to EPA, and the

plan will be available to state and local governments and the public. These regulations will encourage sources to reduce the probability of accidental releases of substances that have the potential to cause immediate harm to public health and the environment and will stimulate the dialogue between industry and the public to improve accident prevention and emergency response practices.

The requirements for a covered process include:

- (1) Prepare and submit a single risk management plan (RMP) (Program 1, 2, or 3), including registration that covers all affected processes and chemicals.
- (2) Conduct a worst-case release scenario analysis; review accident history; ensure emergency response procedures are coordinated with community response organizations to determine eligibility for Program 1; and, if eligible, document the worst case and complete a Program 1 certification for the RMP.
- (3) Conduct a hazard assessment, document a management system, implement a more extensive, but still streamlined prevention program, and implement an emergency response program for Program 2 processes.
- (4) Conduct a hazard assessment, document a management system, implement a prevention program that is fundamentally identical to the OSHA PSM Standard, and implement an emergency response program for Program 3 processes.
- (5) Measures taken by sources to comply with OSHA PSM for any process that meets OSHA's PSM standard are sufficient to comply with the prevention program requirements of all three programs. EPA will retain its authority to enforce the prevention program requirements and the general duty requirements of CAA Section 112(r)(1). EPA and OSHA are working closely to coordinate interpretation and enforcement of PSM and accident prevention programs. EPA will also work with state and local agencies to coordinate oversight of worker, public safety, and environmental protection programs.

G2-8 Reliability Classification

This section describes the three reliability classifications established by EPA for sewerage works.

G2-8.1 Definitions

Reliability standards establish minimum levels of reliability for three classes of sewerage works. The reliability classification shall be established by the owner and approved by Ecology and will be a major consideration for discussion at the preconstruction meeting described in [G2-7.2.3](#).

Pump stations associated with, but physically removed from, the actual treatment works may have a different classification than the treatment works itself. The reliability classification will be based on the water quality and public health consequences of a

component or system failure. Specific requirements pertaining to treatment plant unit processes for each reliability class are described in EPA's technical bulletin, "Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability," EPA 430-99-74-001.

Guidelines for classifying sewerage works are listed in [Table G2-6](#).

Table G2-6. Guidelines for Classifying Sewerage Works

Reliability Class	Guideline
I	<p>These are works whose discharge, or potential discharge, (1) is into public water supply, shellfish, or primary contact recreation waters, or (2) as a result of its volume and/or character, could permanently or unacceptably damage or affect the receiving waters or public health if normal operations were interrupted.</p> <p>Examples of Reliability Class I works are those with a discharge or potential discharge near drinking water intakes, into shellfish waters, near areas used for water contact sports, or in dense residential areas.</p>
II	<p>These are works whose discharge, or potential discharge, as a result of its volume and/or character, would not permanently or unacceptably damage or affect the receiving waters or public health during periods of short-term operations interruptions, but could be damaging if continued interruption of normal operations were to occur (on the order of several days).</p> <p>Examples of a Reliability Class II works are works with a discharge or potential discharge moderately distant from shellfish areas, drinking water intakes, areas used for water contact sports, and residential areas.</p>
III	These are works not otherwise classified as Reliability Class I or Class II.

G2-8.2 Reliability Components

In accordance with the requirements of the appropriate reliability class, capabilities shall be provided for satisfactory operation during power failures, flooding, peak loads, equipment failure, and maintenance shutdown.

Except as modified below, unit operations in the main wastewater treatment system shall be designed so that, with the largest-flow-capacity unit out of service, the hydraulic capacity (not necessarily the design-rated capacity) of the remaining units shall be sufficient to handle the peak wastewater flow. There shall be system flexibility to enable the wastewater flow to any unit out of service to be routed to the remaining units in service.

Equalization basins or tanks will not be considered a substitute for component backup requirements.

General requirements for each reliability classification are summarized in [Table G2-7](#). Specific requirements are described in EPA's technical bulletin, "Design Criteria for Mechanical, Electrical, and Fluid System Component Reliability," EPA 430-99-74-001.

Table G2-7. General Requirements for Each Reliability Classification

Reliability Class	General Requirements
I	<p>For components included in the design of Reliability Class I works, the following backup requirements apply:</p> <ul style="list-style-type: none"> A. Mechanically Cleaned Bar Screens. A backup bar screen, designed for mechanical or manual cleaning, shall be provided. Facilities with only two bar screens shall have at least one bar screen designed to permit manual cleaning. B. Pumps. A backup pump shall be provided for each set of pumps performing the same function. The capacity of the pumps shall be such that, with any one pump out of service, the remaining pumps will have the capacity to handle the peak flow. C. Comminution Facility. If comminution of the total wastewater flow is provided, an overflow bypass with a manually-installed or mechanically-cleaned bar screen shall be provided. The hydraulic capacity of the comminutor overflow bypass should be sufficient to pass the peak flow with all comminution units out of service. D. Primary Sedimentation Basins. The units should be sufficient in number and size so that, with the largest-flow-capacity unit out of service, the remaining units should have a design flow capacity of at least 50 percent of the total design flow. E. Final Sedimentation Basins and Trickling Filters. The units shall be sufficient in number and size so that, with the largest-flow-capacity unit out of service, the remaining units shall have a design flow capacity of at least 75 percent of the total design flow. F. Activated Sludge Process Components. <ul style="list-style-type: none"> 1. Aeration Basin. A backup basin will not be required; however, at least two equal-volume basins shall be provided. (For the purpose of this criterion, the two zones of a contact stabilization process are considered as only one basin.) 2. Aeration Blowers or Mechanical Aerators. There shall be a sufficient number of blowers or mechanical aerators to enable the design oxygen transfer to be maintained with the largest-capacity-unit out of service. It is permissible for the backup unit to be an uninstalled unit, provided that the installed units can be easily removed and replaced. However, at least two units shall be installed. 3. Air Diffusers. The air diffusion system for each aeration basin shall be designed so that the largest section of diffusers can be isolated without measurably impairing the oxygen transfer capability of the system. G. Disinfectant Contact Basins. The units shall be sufficient in number and size so that, with the largest-flow-capacity unit out of service, the remaining units shall have a design flow capacity of at least 50 percent of the total design flow.
II	<p>The Reliability Class I requirements shall apply except as modified below:</p> <p>D/E. Primary and Final Sedimentation Basins and Trickling Filters. The units shall be sufficient in number and size so that, with the largest-flow-capacity unit out of service, the remaining units shall have a design flow capacity of at least 50 percent of the design basin flow.</p>
III	<p>The Reliability Class I requirements shall apply except as modified below:</p> <p>D/E. Primary and Final Sedimentation Basins. There shall be at least two sedimentation basins.</p> <p>F. Activated Sludge Process Components. <ul style="list-style-type: none"> 1. Aeration Basin. A single basin is permissible. 2. Aeration Blowers/Mechanical Aerators or Rotors. There shall be at least two blowers, mechanical aerators, or rotors available for service. It is permissible for one of the units to be uninstalled, provided that the installed unit can be easily removed and replaced. Aeration must be provided to maintain sufficient DO in the tanks to maintain the biota. </p>

G2-8.3 Electrical Power Sources

Two separate and independent sources of electric power shall be provided to the plant either from two separate utility substations or from a single substation and a works-based generator located at the plant. If available from the electric utility, at least one of the power sources shall be a preferred source (that is, a utility source which is one of the last to lose power from the utility grid because of loss of power-generating capacity). In geographical areas where it is projected that, sometime during the design period, the

electric utility might reduce the rated line voltage (i.e., brown-out) during peak utility system load demands, a generator shall be provided as an alternate power source where practicable. As a minimum, the capacity of the backup power source for each class of treatment plant shall be as listed in [Table G2-8](#).

Table G2-8. Minimum Capacity of the Backup Power Source for Each Reliability Classification

Reliability Class	Minimum Capacity
I	Sufficient to operate all vital components and critical lighting and ventilation during peak wastewater flow conditions.
II	The same as Reliability Class I, except that vital components used to support the secondary processes (i.e., mechanical aerators or aeration basin air compressors) need not be operable to full levels of treatment, but shall be sufficient to maintain the biota.
III	Sufficient to operate the screening or comminution facilities, the main wastewater pumps, the primary sedimentation basins, the disinfection facility, and critical lighting and ventilation during peak wastewater flows.

G2-9 Laboratory, Personnel, and Maintenance Facilities

This section describes requirements for laboratory, personnel, and maintenance facilities.

G2-9.1 General

Minimum standards are presented in this section for laboratory, personnel, and maintenance facilities.

G2-9.2 Laboratory Facilities

G2-9.2.1 General

See the EPA publication, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" (1973) for guidelines on laboratory facilities.

G2-9.2.2 Space Requirements

A method for determining bench space is to provide 12 to 25 lineal feet of bench space per analyst working in the lab at any given time. An analyst doing very limited testing (e.g., pH, TSS, residual chlorine) may need only 12 lineal feet, while an analyst doing more extensive testing (e.g., BOD and fecal coliforms, in addition to those mentioned above) may need closer to 25. Likewise, floor space should vary from 150 to 300 square feet per analyst depending on the number and type of tests performed.

G2-9.2.3 Design

The following factors should be key considerations in designing plant laboratories:

- **Flexibility**, to help plant management adapt to changes in use requirements.

- **Adaptability**, to allow for changes in occupancy requirements.
- **Expandability**, to provide for changes in space requirements.

A. Location

The laboratory should be located at ground level, easily accessible to all sampling points. To ensure sufficient environmental control, the laboratory shall be located away from vibrating machinery or equipment that might have adverse effects on the performance of laboratory instruments or the analyst.

B. Layout

Efficient laboratory operation depends largely on the physical layout of the laboratory. The physical layout includes items such as working area arrangement, the number and location of sinks and electrical outlets, the arrangement of laboratory equipment, materials of construction, and lighting. The details of the layout can affect the accuracy of the laboratory tests. For example, tests that include identification of some colorimetric end points can be drastically affected by the type of lighting and the finishes on laboratory facilities.

The factors listed in the following subsections should be considered when laying out a laboratory.

1. General

- Adequate lighting should be provided. Fluorescent lighting is recommended.
- Wall and floor finishes should be nonglare-type and light in color. Flat-finish wall paint is recommended. Floor finishes should be a single color for ease in locating small items that have been dropped.
- Floor covering, in addition to being nonglare and slip resistant, should be easy to clean and comfortable.
- Doors should have large glass windows for visibility into and out of the laboratory. There should be no obstructions near the doors.
- Aisle width between work benches should be at least 4 feet. Adequate spacing should be provided around free-standing equipment, workbenches, and file cabinets to facilitate cleaning.
- Electrical receptacles should be provided at strategic points for convenient and efficient operation of the laboratory. Duplex-type receptacles should be spaced at 3-foot intervals along benches used for laboratory tests. Strip molding receptacles may be used.
- If needed, gas and vacuum fixtures should be provided at convenient locations for every 15-foot length of bench used for laboratory tests.

- The use of an automatic dishwasher should be considered. Where dishwashers are provided, some sinks can be replaced by cup sinks.
- Give special consideration to equipment when laying out the laboratory facility. Pieces of equipment used for performing common tests should be nearby. For example, the drying oven used in making total, suspended, and dissolved solids tests should be close to the muffle furnace for use in determining total volatile solids and volatile suspended solids from the samples dried in the drying oven. The drying oven and the muffle furnace should be near the balance table because the balance is used in the weight determinations for the various solids tests.

2. Storage and Cabinets

- Storage space for reagent stock should be under workbenches. Reagent containers removed from storage areas under workbenches are less likely to be dropped than reagent containers removed from storage in the inconvenient and hard-to-reach areas above the workbenches. Only items that are infrequently used or chemicals of a nonhazardous nature should be stored above workbenches. Strong acids or bases should be stored within convenient reach of the laboratory personnel, preferably beneath or adjacent to the fume hood.
- Sufficient cabinet and drawer space should be provided for the storage of equipment and supplies. Wall cabinets should be no more than 30 inches above the workbench top so that the contents of the top shelving can be reached. The base cabinets under the workbenches should contain a combination of drawers and storage spaces for large items. All cabinets and drawers should be acid-resistant.

3. Sinks

- One sink with a large gooseneck faucet, large enough to wash laboratory equipment, should be provided for every 25 to 30 feet of bench length. One sink should be sufficient when total bench length is less than 25 feet. The minimum size of this sink should be 21 1/2 inches by 15 1/2 inches by 8 inches, and it should be made of chemical-resistant material.
- Cup sinks, also of chemical-resistant material, should be provided at strategic locations on the bench surface to facilitate laboratory testing. The number of cup sinks depends largely on the type of tests that will be run; the general rule is one cup sink for every 25 to 30 feet of bench length. Cup sinks should be alternated with the wash sinks at 12- to 15-foot intervals.
- Where workbench assemblies are provided in the center of the laboratory, a trough-type sink down the center of the workbench may be provided in lieu of cup sinks. A hot and

cold water tap should be placed about every 5 to 10 feet along the trough.

4. Benches and Tables

- Bench tops should be suitable for heavy-duty work and resistant to chemical attack. Resin-impregnated natural stone and other manmade materials provide such a surface and should be used.
- Bench surfaces should be 36 inches high for work done from a standing position and 30 inches high for work done while sitting.
- Bench surfaces should be at least 30 inches wide.
- A separate table is desirable for microscopes. This table should be about 30 inches long, 24 inches deep, and 27 inches high.
- The analytical balance should be located on a separate table of the type sold specifically for the use of analytical balances. The table should not transmit vibrations that would adversely affect the operation of the balance. Using a slab of dense material (such as 4-inch thick granite, concrete, or slate) is sufficient to dampen vibrations.

5. Air Handling

- Fume hoods should be near the area where most laboratory tests are made. Hoods should provide an airflow between 50 and 125 cfm/sf of face area.
- Where air conditioning is desirable, laboratories should be separately air conditioned, with external air supply for 100-percent makeup volume. Separate exhaust ventilation should be provided.

6. Safety

- Safety is a prime consideration of a laboratory. The first aid kit, fire extinguisher, eye wash, and emergency shower should be near the main working area of the laboratory. If the safety shower is not provided in a separate shower stall, a floor drain should be nearby.
- Sources of startling noises, such as alarms or composite sampling equipment, should be located at sites remote or otherwise isolated from the laboratory.

G2-9.3 Personnel Facilities

Personnel facilities are generally located in the administration building. This building serves the needs of the supervisory staff, the operation and maintenance personnel, and often the laboratory staff. Sewer maintenance personnel may also share the administration building. However, facilities for the laboratory and operations and maintenance staff need not be provided in the administration building, even though this is customary.

A wastewater treatment plant staffed for 8 hours or more each day should contain support facilities for the staff. Toilets shall be provided in conformance with applicable building codes. The following should also be provided:

- **Washing and changing facilities.** These should include showers, lockers, sinks, and toilets sufficient for the entire staff at design conditions. A heated and ventilated mudroom is desirable for changing and storing boots, jackets, gloves, and other outdoor garments worn on the job. Each staff member should have separate lockers for street clothes and plant clothes. Separate washing and changing facilities should be available for men and women, with the exception of the mudroom.
- **Eating facilities.** Provide a clean, quiet area with facilities for storage and eating light meals.
- **Meeting facilities.** Provide a place to assemble the plant staff and visitors. In most cases, the meeting facilities and the eating facilities will be the same.
- **Supervisors' facilities.** Provide a place where discussion and writing can be carried out in private.

Small treatment plants that are not staffed 8 hours a day need not contain all of the personnel facilities required for larger plants, but shall have a room with a door capable of being locked and contain at a minimum a toilet and lavatory.

G2-9.4 Maintenance Facilities

To ensure adequate maintenance of equipment, convenient maintenance facilities should be available. Such facilities generally include a maintenance shop, a garage, storage space, and yard maintenance facilities.

Access to nearby municipal garages and other maintenance centers should be considered. Duplication of facilities should be avoided where possible.

G2-9.4.1 Maintenance Shop

A separate maintenance shop should be designated where treatment plant equipment and vehicles can be repaired. The maintenance shop should be provided with the following facilities:

- Work space with adequate area and lighting, including a workbench with vise.
- Conveyance to move heavy items from the point of delivery to the appropriate work space.
- Storage for small tools and commonly used spare parts.
- Adequate power outlets and ratings for the equipment.

The shop should be laid out such that it is readily accessible to maintenance vehicles and personnel. Adequate space for present maintenance operations and a reasonable allowance for the future are important. The shop may be part of the administration building or the garage.

G2-9.4.2 Vehicle Requirements

Maintenance and transportation vehicles should be provided for the treatment plant staff. Sludge hauling trucks are also required for many treatment plants.

A garage and storage area should be included in the treatment plant for protection of the plant's vehicles.

G2-9.4.3 Storage Requirements

Storage space should be provided for plants, fuels, oils and lubricants, grounds maintenance equipment, spare parts, and collection system equipment.

In larger facilities it may be desirable to have a separate storage building for paints, fuel, oils and lubricants, spare parts, yard supplies, and so on. For storing flammable materials, the requirements of the Uniform Building Code shall be met. In smaller facilities it might be desirable to combine storage with the shop or garage so that the stored material can be protected against unauthorized use.

G2-9.4.4 Yard Requirements

A landscaped yard helps soften the visual impact of a treatment facility. Shrubs and trees judiciously located can screen unsightly areas from public view. Care must be taken that the plantings do not become a hindrance to operation. Deciduous leaves falling in clarifiers can hinder skimming and add unnecessarily to the digester loading. Roots from trees too close to pipes can cause clogging.

Sidewalks and roadways through the yard should provide convenient access to the facility's equipment. Lighting shall be adequate for safe nighttime operation. Handrails should be placed along side stairs and around open basins.

A basin washdown system should have enough hose bibbs, with a sufficient length of hose and hose racks, to expedite the washdown of the basins. The irrigation system should allow convenient watering of the lawn, shrubs, and trees. Both systems often are supplied from treatment plant effluent, and care must be taken to prevent cross-connections with the potable water source.

Yard maintenance requires its own complement of equipment and tools for irrigation, lawn mowing, fertilizing and weed control, shrub and tree care, and sidewalk and roadway cleaning. Provisions should be made for storage of such equipment. Yard maintenance equipment may be stored in the garage or the facility storage building.

G2-10 References

American Society of Civil Engineering. Sulfide in Wastewater Collection and Treatment Systems. ASCE Manuals and Reports on Engineering Practice, No. 69. 1989.

Chow, Ven Te. Open Channel Hydraulics. McGraw-Hill, Inc., 1959.

Grant, Douglas M. Isco Open Channel Flow Measurement Handbook. Fourth Edition (Revised). 1995.

Instrument Society of America. Standards and Practices for Instrumentation. Volume 1, Eleventh Edition, Standard No. S5.1. 1991.

Sanks, Robert L., et al. Pumping Station Design. Butterworth Publishers, 1989.

US Environmental Protection Agency. Design Criteria for Mechanical, Electrical, and Fluid System Component Reliability. Publication No. EPA 430-99-74-001. 1974.

US Environmental Protection Agency. Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities. Publication No. EPA 430-9-74-002. 1973.

Water Environment Federation. Odor Control in Wastewater Treatment Plants. Manual of Practice No. 22. 1995.